

# Trade Liberalization and Investment: Evidence from the U.S. Granting of PNTR to China\*

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## Abstract

This paper examines the effect of a change in U.S. trade policy on the investment behavior of manufacturing establishments. 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. However, an examination of heterogeneous responses within industries reveals that this effect is concentrated among establishments with low initial levels of capital intensity, skill intensity and labor productivity. Consistent with a reduction in uncertainty, we also find evidence that establishments' investment activity becomes less lumpy following the policy change.

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# 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 for domestic producers. While a growing body of research shows that some firms responded to this trade liberalization by shrinking their employment or exiting, less is known about the extent to which others adapted by investing in new technologies, changing their product mix, or otherwise differentiating themselves from their new competitors.<sup>1</sup>

In this paper, we examine how the 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 engage in finding Chinese suppliers, moving production from the United States to China, and adopting technologies that might increase their competitiveness in the face of rising Chinese import competition. The investment data examined here are well-suited to exploring the latter channel.<sup>2</sup>

Our empirical analysis takes place in three steps. First, we examine the relationship between exposure to PNTR and investment and capital stock at the industry-level. Because the establishment-level investment response to PNTR is ambiguous – some establishments may shrink or exit, lowering investment, while others make additional investments to alter their production process – this step is important for assessing a net industry-level effect. Second, we turn to confidential U.S. Census Bureau microdata and examine how individual establishments adjust their investment in response to PNTR. Third, we examine the timing, frequency, and lumpiness of establishment-level investment, examining how these attributes of investment change in response to PNTR. We compare our findings in this third step to predictions from the literature on investment under uncertainty.

Our empirical analysis employs a generalized differences-in-differences (DID) identification strategy that estimates how investment and capital change after the granting of PNTR for industries and establishments with varying levels of exposure. The baseline DID specification includes controls for other factors that may affect investment in manufacturing during our sample period, including changes in Chinese trade pol-

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<sup>1</sup>Consider, for example, this quote from a recent article in the Wall Street Journal (Michaels 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 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.”

<sup>2</sup>In earlier work (Pierce and Schott 2016a), we show that products more exposed to PNTR exhibited substantial increases in U.S. imports from China as well as the number of U.S. firms that import from China and the number of U.S.-Chinese firm pairs engaged in a trading relationship. One interpretation of these results is that they are a manifestation of investment in these trading relationships.

icy 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 and the production of advanced technology products.

At the industry-level, we find that industries that are more exposed to PNTR experience relative declines in manufacturing investment, and that the timing of the declines corresponds closely to the implementation of PNTR. More-exposed industries experience negative but statistically insignificant declines in the capital stock, both for structures and equipment. The less precise relationship between exposure to PNTR and the capital stock likely is related to the relatively slow response of capital stocks to changes in investment flows.

At the establishment-level, we find that for *continuing* establishments, there is a negative but statistically insignificant relationship between exposure to PNTR and both investment and capital stocks, implying that a portion of the negative industry-level response is being driven by declines in investment associated with establishment exit. Among these continuing establishments, however, there is some evidence that for plants with certain characteristics, higher exposure to PNTR is associated with increased investment. In contrast to the overall relative reduction in investment associated with PNTR, investment at plants with higher initial levels of labor productivity and capital intensity is largely unaffected by the policy change. For plants with high initial levels of skilled labor intensity, higher exposure to PNTR is associated with a relative increase in investment. These results suggest that trade liberalization may have induced increased investment among establishments whose attributes are more in line with U.S. comparative advantage.

Turning to the frequency and lumpiness of investment behavior, we use annual data to measure the average size of establishments’ investment, the standard deviation (lumpiness) of that investment across years, and the share of years with positive investment (frequency of investment). Here, too, accounting for heterogeneity in establishment responses is important. In specifications that control for plants’ initial levels of productivity, we find that industries with higher exposure to PNTR – and therefore larger reductions in tariff rate uncertainty – exhibit relative reductions in the standard deviation of investment size across years. This response is consistent with Bloom, Bond and Van Reenen’s (2007) finding that the elimination of uncertainty increases the responsiveness of investment to demand shocks.

Our analysis makes three contributions to the literature. First, it estimates the relationship between a major trade liberalization and U.S. manufacturing investment. While the substantial decline in U.S. manufacturing employment since 2000 is well-known, our finding that higher exposure to PNTR’s trade liberalization is associated with lower industry-level investment may help explain a reduction in manufacturing investment and flattening of the capital stock that occurs around the same time. Furthermore, this research complements the growing literature on labor market and other

responses to increased competition from low-wage countries.<sup>3</sup> Our finding of effects on investment may provide information on the potential persistence of employment effects if depressed investment lowers future employment.

Second, it shows that investment responses to trade liberalization are heterogeneous within industries, and identifies the characteristics of establishments – including higher labor productivity and higher capital and skilled labor intensity, – that are associated with stronger investment responses in the face of increased import competition. These findings add additional context to work presenting evidence for trade-induced technical change among U.K. manufacturers by Bloom, Draca and Van Reenen (2016) and to research by Autor et al. (2016) finding evidence for reduced patenting activity associated with import competition. Our work is closely related to a recent paper by Guttierrez and Phillipon (2017), which studies how changes in industry competitiveness induced by increased import competition from China affect firms’ investment and capital stocks. In that paper, the authors use Compustat data for a set of publicly traded manufacturing firms and find that increased competition associated with PNTR induces “leader” firms to increase investment, even as smaller “laggard” firms exit. Here, our use of the Census of Manufactures allows us to consider the full population of manufacturing establishments, while also observing a broader range of indicators of establishment heterogeneity.

Third, we provide new evidence on the relationship between uncertainty and investment. In a theoretical literature, Pindyck (1993) and Rob and Vettas (2003) finds that the effect of uncertainty on investment can depend on whether the uncertainty relates to output demand, input costs or technological uncertainty. Finding plausibly exogenous shocks to uncertainty, however, is an important challenge for empiricists taking these insights to the data. A group of authors including Guiso and Pirigi (1999), Schwartz and Zozaya-Gorostiza (2003), and Bloom, Bond and Van Reenen (2007) have found novel ways to measure and estimate the effects of uncertainty on investment using survey-based measures of uncertainty, cost data for specific information technology investments and detailed information from firms’ annual reports, respectively. Here, PNTR provides a large and plausibly exogenous shock to uncertainty, allowing us to identify effects on investment in a large developed economy.<sup>4</sup> Furthermore, our setting 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 about future tariff rates.

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.

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<sup>3</sup>For example, Bernard, Jensen and Schott (2006), Autor, Dorn and Hanson (2013), Ebenstein et al. (2014b), Pierce and Schott (2016a), Feler and Senses (2016), McManus and Schaur (2015), Pierce and Schott (2016b), and Autor, Dorn and Hanson (2017).

<sup>4</sup>Our research here contributes to the growing literature on uncertainty and trade instigated by Handley (2014).

## 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, Census includes questions asking 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 U.S.manufacturing establishments’ total investment (capital expenditures) in each Census year, as well as this investment as a share of their capital stock and the share of establishments with positive investment. In each case, we also report figures for structures and equipment investment. Total establishment-level investment averages 905 thousand dollars 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 about 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 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.

	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	767	138	11%	2%	10%	87%	86%	44%
1997	970	838	132	15%	2%	13%	89%	89%	55%
2002	790	676	113	13%	1%	12%	93%	92%	38%
2007	954	808	146	16%	2%	14%	90%	90%	54%

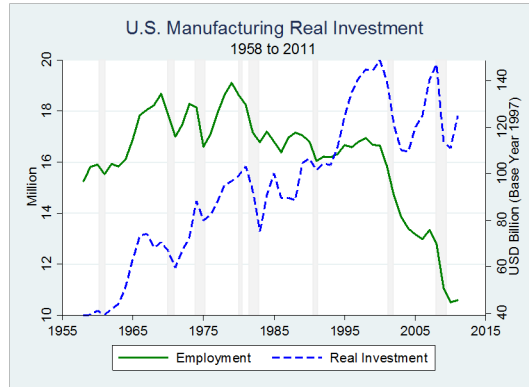
Manufactures years. All investment and capital stock data are deflated using the price indexes in the NBER-CES Manufacturing Industry Database. Sample excludes administrative records. Source: U.S. Census Bureau's Census of Manufactures.

Table 1: PNTR and Industry-Level Capital Stock

For the portion of our analysis where we investigate attributes of investment that must be estimated across time—e.g., average investment per year or the extent to which investment is “lumpy”—we also use data from the ASM. The CM and ASM collect similar

information, but are different in two respects. First, the ASM is conducted every year. Second, it collects information from only a subset of plants. When using these data, we must therefore restrict our analysis to the establishments that are surveyed in every year across our 1992 to 2007 sample period.<sup>5</sup> While this sample is restricted, these long-lived plants typically account for a disproportionately large share of activity in the manufacturing sector.

Our industry-level analysis makes use of the publicly available NBER-CES Manufacturing Industry Database assembled by Becker, Gray and Marvakov (2016), 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, which can be decomposed into 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.<sup>6</sup> However, because investment 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.<sup>7</sup>



Source: NBER-CES Manufacturing Industry Database.

Figure 1: Manufacturing Employment versus Real Investment

<sup>5</sup>This restriction arises from changes in the sampling frame for the ASM that occur every five years. 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.

<sup>6</sup>Becker et al. (2016) convert the nominal information on total capital expenditures 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.

<sup>7</sup>For 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.

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 2002 to 2004, the first time it had registered a decline in the post-World War Two era (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.

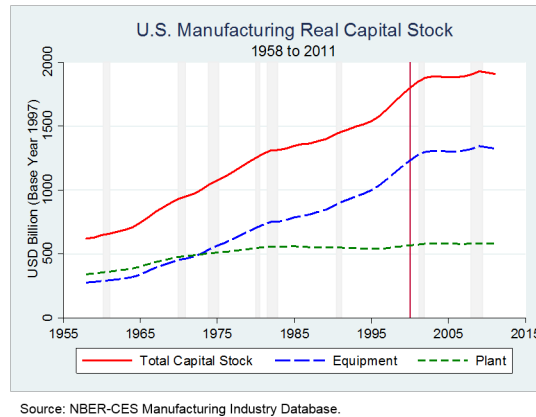


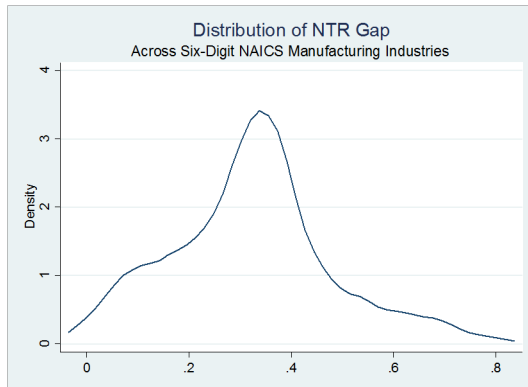
Figure 2: Manufacturing Capital Stock

## 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. 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 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 such 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 (2016a) 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,

$$NTR\ Gap_j = Non\ NTR\ Rate_j - NTR\ Rate_j. \quad (1)$$

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 et al. (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 (2016a) 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, while less than 1 percent of variation is due to variation in NTR rates. 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 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 et al. (2012). To account for the fact that reductions in barriers to foreign investment to China also declined at this time, we also control for Nunn’s (2007) measure of the share of inputs requiring relationship-specificity.

Finally, we control for other policy and macroeconomic shifts occurring in the U.S. around 2000. The first of these changes includes 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. Finally, 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

PNTR’s impact on investment might vary across manufacturing firms and establishments for a number of reasons. In this section we set the stage for the establishment-level regressions that follow by examining the overall impact of PNTR on industry investment.

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,

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

The sample period 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, union membership 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 year (1992) industry capital and skill intensity or the degree to which industries encompass high-technology products. 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.  $\delta_j$ ,  $\delta_t$  and  $\alpha$  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.

	$\ln(\text{Total}_{i,t})$	$\ln(\text{Total}_{i,t})$	$\ln(\text{Total}_{i,t})$	$\ln(\text{Structures}_{i,t})$	$\ln(\text{Structures}_{i,t})$	$\ln(\text{Structures}_{i,t})$	$\ln(\text{Equipment}_{i,t})$	$\ln(\text{Equipment}_{i,t})$	$\ln(\text{Equipment}_{i,t})$	$\ln(\text{Emp}_{i,t})$	$\ln(\text{Emp}_{i,t})$	$\ln(\text{Emp}_{i,t})$
Post x NTR Gap <sub>j</sub>	-0.780	-0.905	-0.557	-1.139	-1.047	-0.719	-0.802	-0.884	-0.562	-0.785	-0.610	-0.308
	0.189	0.190	0.181	0.246	0.245	0.246	0.186	0.199	0.198	0.150	0.150	0.145
Post x $\ln(K/\text{Emp})_j$		-0.086	-0.149		-0.003	-0.077		-0.057	-0.116	0.030	-0.039	
		0.037	0.045		0.050	0.059		0.040	0.045	0.027	0.029	
Post x $\ln(\text{NP}/\text{Emp})_j$		0.346	0.421		0.284	0.408		0.239	0.347	0.242	0.257	
		0.069	0.072		0.097	0.113		0.072	0.080	0.056	0.057	
Post x Contract Intensity <sub>j</sub>			-0.080			-0.191			-0.028			-0.138
			0.178			0.228			0.169			0.114
Post x $\Delta$ China Import Tariffs <sub>j</sub>			-0.005			-0.008			-0.004			-0.001
			0.002			0.003			0.002			0.001
Post x $\Delta$ China Subsidies <sub>j</sub>			0.032			0.053			0.046			0.012
			0.022			0.029			0.022			0.015
Post x $\Delta$ China Licensing <sub>j</sub>			-0.864			-0.601			-0.720			-0.628
			0.283			0.374			0.303			0.194
Post x 1{Advanced Technology <sub>j</sub> }			0.010			-0.006			-0.057			0.002
			0.078			0.105			0.079			0.053
MFA Exposure <sub>i,t</sub>			0.004			0.005			0.005			0.003
			0.002			0.003			0.002			0.002
NTR <sub>i,t</sub>			-0.020			-0.021			-0.017			-0.020
			0.003			0.004			0.003			0.003
Post x U.S. Union Membership <sub>j</sub>			0.267			0.506			0.123			-0.078
			0.494			0.587			0.388			0.280
Observations	6,468	6,468	6,468	6,468	6,468	6,468	6,468	6,468	6,468	6,468	6,468	6,468
R-Squared	0.92	0.92	0.93	0.83	0.83	0.83	0.93	0.93	0.93	0.96	0.96	0.96
Fixed Effects	i,t	i,t	i,t	i,t	i,t	i,t	i,t	i,t	i,t	i,t	i,t	i,t
Implied Impact of PNTR	-0.147	-0.170	-0.105	-0.214	-0.197	-0.135	-0.151	-0.166	-0.106	-0.148	-0.115	-0.058

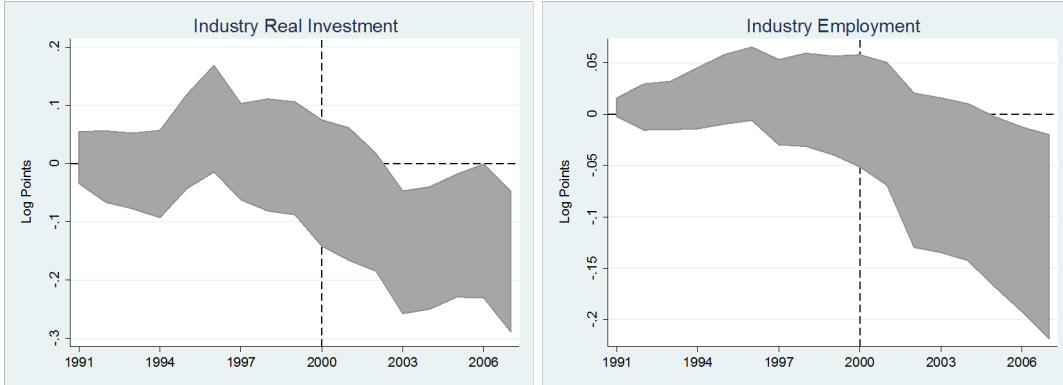
Note: Table reports results of unweighted OLS generalized difference-in-differences regressions. The dependent variable is the log of industry-year investment (total, structures, or equipment) or employment and the independent variable representing the effect of PNTR is the interaction of the NTR gap 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 (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 2: PNTR and Industry-Level Investment

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-NTR 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 0.402 to 0.214). These coefficients indicate that an interquartile shift in industry exposure to PNTR is associated with declines in investment of -0.131 to -0.168 log points (e.g.,  $-0.696 \times 0.188$  to  $-1.017 \times 0.188$ ). 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.

For comparison, the final three columns of Table 2 report results for employment. As in Pierce and Schott (2016a), we find that higher NTR gaps are associated with lower employment in all three specifications, with the absolute magnitudes of the coefficients declining as additional controls are added. Results are statistically significant at conventional levels in all three cases. Interquartile shifts in exposure to PNTR are associated with declines in employment of between -0.083 and -0.167 log points.



Source: NBER-CES Manufacturing Industry Database and authors' calculations. Figures display the 95 percent confidence intervals associated with an interquartile shift in industry exposure to PNTR.

Figure 4: Implied Industry-Level Impact of PNTR

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,

$$y_{jt} = \sum_{y=1991}^{2007} (\theta_y 1\{y = t\} \times NTR\ Gap_j) + \quad (3)$$

$$\sum_{y=1991}^{2007} (\lambda_y 1\{y = t\} \times \mathbf{X}_j) + \quad (4)$$

$$\beta \mathbf{X}_{jt} + \delta_j + \delta_t + \alpha + \varepsilon_{it}.$$

Here, we estimate equation 3 with the full set of controls noted above. Results are reported visually in Figure 4, which traces out the impact on investment and employment of an interquartile shift in industry exposure to PNTR implied by the estimated difference-in-differences coefficients  $\theta_y$ . As indicated in 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.

We examine whether the decline in investment associated with PNTR in Table 2 is also apparent in capital stocks. The first three columns of Table 3 report results for industries' aggregate capital stock. As indicated in the table, we find that capital stocks are negatively related to exposure to PNTR in the post period, but that these relationships are not statistically significant at conventional levels. The next six columns report results for the components that make up the aggregate capital stock, equipment and structures. As indicated in the table, we find negative relationships in all six columns, but again the coefficient estimates are not statistically significant. One potential reason for the coefficient on the DID term to be less precisely estimated in regressions for capital, relative to those for investment, is that the capital stock adjusts slowly to changes in investment flows.

	ln(K <sub>i,t</sub> )	ln(K <sub>i,t</sub> )	ln(K <sub>i,t</sub> )	ln(Equipment <sub>i,t</sub> )	ln(Equipment <sub>i,t</sub> )	ln(Equipment <sub>i,t</sub> )	ln(Structures <sub>i,t</sub> )	ln(Structures <sub>i,t</sub> )	ln(Structures <sub>i,t</sub> )
Post x NTR Gap <sub>i</sub>	0.019	-0.105	-0.072	-0.030	-0.114	-0.122	0.047	-0.121	-0.057
	0.082	0.100	0.102	0.061	0.076	0.079	0.098	0.117	0.119
Post x ln(K/Emp <sub>i,1990</sub> )		-0.072	-0.077		-0.048	-0.046		-0.092	-0.101
		0.016	0.018		0.012	0.014		0.019	0.021
Post x ln(NP/Emp <sub>i,1990</sub> )		0.234	0.188		0.152	0.124		0.275	0.223
		0.033	0.038		0.025	0.028		0.039	0.045
Post x Contract Intensity <sub>i</sub>			-0.055			-0.049			-0.057
			0.071			0.054			0.086
Post x ΔChina Import Tariffs <sub>i</sub>			-0.001			-0.002			-0.001
			0.001			0.001			0.001
Post x ΔChina Subsidies <sub>i</sub>			-0.002			0.001			-0.003
			0.011			0.008			0.013
Post x ΔChina Licensing <sub>i</sub>			-0.230			-0.080			-0.346
			0.129			0.093			0.157
Post x 1{Advanced Technology <sub>i</sub> }			0.124			0.113			0.123
			0.048			0.040			0.053
MFA Exposure <sub>i,t</sub>			-0.001			0.000			-0.001
			0.001			0.001			0.001
NTR <sub>i,t</sub>			-0.005			-0.002			-0.006
			0.001			0.001			0.001
U.S. Union Membership <sub>i,t</sub>			-0.251			-0.222			-0.188
			0.203			0.137			0.261
Observations	6,468	6,468	6,468	6,468	6,468	6,468	6,468	6,468	6,468
R-Squared	0.99	0.99	0.99	0.99	0.99	0.99	0.98	0.99	0.99
Fixed Effects	i,t	j,t	j,t	j,t	j,t	j,t	j,t	j,t	j,t
Implied Impact of PNTR	0.004	-0.020	-0.014	-0.006	-0.021	-0.023	0.009	-0.023	-0.011

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 (i) 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 employment. 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

The relative declines in capital stock and structures found above may contribute to the decline in overall manufacturing investment and flattening of the capital stock that occurs around 2000, as indicated in Figure 2. Furthermore, the relative weakening in investment may help explain the persistence of the reduction in manufacturing employment associated with PNTR (Pierce and Schott 2016a). 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.

## 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 both the level and frequency of investment is less likely to be disturbed by the change in U.S. trade policy for larger, more productive and more skill and capital intensive plants. This message is clearest

with respect to the impact of plant labor productivity on equipment investment.

## 4.1 Heterogeneous Investment Responses to Trade Liberalization

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,

$$y_{pt} = \theta Post PNTR_t \times NTRGap_j + \tag{5}$$

$$\gamma Post PNTR_t \times \mathbf{X}_j + \beta \mathbf{X}_{jt} + \tag{6}$$

$$+\delta_p + \delta_t + \alpha + \varepsilon_{pt}.$$

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.

	Total Investment <sub>it</sub>	Total Investment <sub>it</sub>	Structures Investment <sub>it</sub>	Structures Investment <sub>it</sub>	Equipment Investment <sub>it</sub>	Equipment Investment <sub>it</sub>	Log Capital <sub>it</sub>	Log Capital <sub>it</sub>
Post x NTR Gap <sub>i</sub>	-0.044 0.028	-0.018 0.016	-0.014 0.008	-0.003 0.004	-0.030 0.021	-0.014 0.013	-0.116 0.172	0.064 0.179
Post x ln(K/Emp <sub>it,1990</sub> )		-0.009 0.003		0.001 0.001		-0.010 0.002		-0.002 0.039
Post x ln(NP/Emp <sub>it,1990</sub> )		0.022 0.005		0.003 0.002		0.019 0.005		0.014 0.069
Post x Contract Intensity <sub>i</sub>		-0.006 0.012		-0.002 0.003		-0.004 0.010		0.231 0.158
Post x DChina Subsidies <sub>i</sub>		4.513 0.841		0.952 0.222		3.561 0.690		23.159 9.575
Post x DChina Licensing <sub>i</sub>		0.046 0.029		0.008 0.006		0.038 0.025		0.791 0.343
Post x 1{Advanced Technology <sub>it</sub> }		-0.002 0.008		0.001 0.002		-0.002 0.007		-0.140 0.106
Post x Union Membership <sub>i</sub>		0.0003 0.0002		0.000 0.000		0.000 0.000		-0.007 0.002
MFA Exposure <sub>it</sub>		-0.001 0.000		0.000 0.000		-0.001 0.000		-0.019 0.003
NTR <sub>it</sub>		0.019 0.057		-0.017 0.019		0.036 0.049		0.562 0.984
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	0.90	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 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

The first two columns of Table 4 report the results of estimating equation 5, 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.

To assess the importance of plant heterogeneity within industries, we augment Equation 5 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. The normalization involves dividing the 1992 plant attribute by the average of that attribute across all plants in

the same industry in 1992.<sup>8</sup> With this normalization, these terms account explicitly for heterogeneity within industries rather than differences across industries. We refer to these triple-interaction DID terms as “plant heterogeneity terms” below and in the notes to the tables, and include a different one in each regression,

$$\begin{aligned}
 y_{pt} = & \theta_1 Post PNTR_t \times NTR Gap_j + \\
 & \theta_2 Post PNTR_t \times NTR Gap_j \times EstabChar_p + \\
 & \varphi_1 Post PNTR_t \times EstabChar_p + \beta \mathbf{X}_{jt} + \gamma Post PNTR_t \times \mathbf{X}_j + \\
 & \delta_p + \delta_t + \alpha + \varepsilon_{pt}.
 \end{aligned} \tag{7}$$

The third term in this specification 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.

Results for the equipment investment share are reported in Table 5. Each plant employs a different plant attribute for the plant heterogeneity term. A key difference between these results and those reported in Table 4, which do not include plant heterogeneity terms, is that the main DID terms of interest in the first row of the table are negative, as before, but are now statistically significant at conventional levels in all except the second column, where the plant heterogeneity term accounts for plant size in terms of real value added. The plant heterogeneity terms themselves, reported in the second row of the table, are positive in all columns and statistically significant in the final four columns, i.e., for both measures of labor productivity and for capital and skill intensity. These positive coefficients indicate that plants with higher values of these attributes exhibit relatively larger levels of equipment investment after the change in trade policy.

As noted in the bottom panel of the table, the impact of an interquartile shift in industry exposure on the equipment investment share implied by these regressions varies from a high in absolute magnitude of -0.004 in the first (-0.0229\*0.188+0.0022\*0.188\*1.1176) and sixth columns of the table (where employment and capital intensity, respectively, are the plant heterogeneity attributes), to a low of -0.002 in the last column (skill intensity). In each case, these impacts are evaluated at the mean 1992 level of each attribute. These changes represent -1.1 to -3.0 percent of the mean equipment investment share in 1997, the prior year closest to the change in trade policy.

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<sup>8</sup>Given 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.



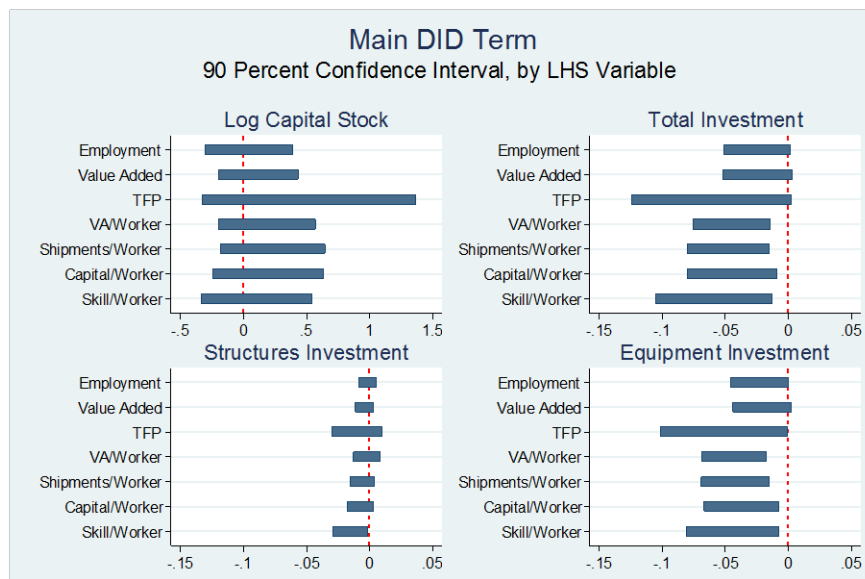
	Equipment Investment <sub>pt</sub>	Equipment Capital <sub>pt</sub>	Equipment Investment <sub>pt</sub>	Equipment Investment <sub>pt</sub>	Equipment Investment <sub>pt</sub>	Equipment Investment <sub>pt</sub>	Equipment Capital <sub>pt</sub>
Post x NTR Gap <sub>j</sub>	-0.0229 0.0139	-0.0206 0.0140	-0.0513 0.0306	-0.0429 0.0155	-0.0420 0.0164	-0.0373 0.0179	-0.0443 0.0221
Post x NTR Gap <sub>j</sub> x Attribute <sub>p</sub>	0.0022 0.0016	0.0009 0.0019	0.0349 0.0280	0.0238 0.0090	0.0242 0.0096	0.0144 0.0081	0.0367 0.0209
Post x ln(K/Emp) <sub>j,1990</sub>	-0.0029 0.0073	0.0001 0.0057	0.0011 0.0056	-0.0001 0.0057	-0.0004 0.0056	-0.0008 0.0057	-0.0024 0.0072
Post x ln(NP/Emp) <sub>j,1990</sub>	-0.0032 0.0097	0.0002 0.0091	0.0051 0.0118	-0.0008 0.0105	0.0003 0.0100	0.0004 0.0096	-0.0048 0.0102
Post x Contract Intensity <sub>j</sub>	3.5420 0.6736	3.5699 0.6044	3.5886 0.6929	3.5633 0.6069	3.7054 0.6267	3.6112 0.6146	3.7565 0.7351
Post x DChina Subsidies <sub>j</sub>	0.0384 0.0248	0.0373 0.0204	0.0310 0.0227	0.0353 0.0209	0.0354 0.0208	0.0360 0.0219	0.0370 0.0261
Post x DChina Licensing <sub>j</sub>	0.0002 0.0001	0.0002 0.0001	0.0002 0.0001	0.0002 0.0001	0.0002 0.0001	0.0002 0.0001	0.0003 0.0001
Post x 1{Advanced Technology <sub>j</sub> }	-0.0102 0.0020	-0.0110 0.0020	-0.0100 0.0021	-0.0095 0.0020	-0.0093 0.0019	-0.0091 0.0018	-0.0101 0.0020
Post x Union Membership <sub>j</sub>	0.0199 0.0042	0.0227 0.0043	0.0222 0.0045	0.0197 0.0043	0.0193 0.0043	0.0194 0.0042	0.0189 0.0046
MFA Exposure <sub>jt</sub>	-0.0008 0.0002	-0.0008 0.0002	-0.0008 0.0002	-0.0008 0.0002	-0.0008 0.0002	-0.0008 0.0002	-0.0008 0.0002
NTR <sub>jt</sub>	0.0374 0.0481	0.0397 0.0468	0.0448 0.0475	0.0536 0.0477	0.0525 0.0480	0.0745 0.0466	0.0435 0.0494
Post x Attribute <sub>p</sub>	-0.0008 0.0004	-0.0010 0.0006	-0.0873 0.0381	-0.0121 0.0032	-0.0130 0.0032	-0.0093 0.0021	-0.0100 0.0080
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 <sub>p</sub>	Employment	VA	TFP	VA per Worker	Shipments per Worker	Capital per Worker	Skill per Worker
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	-0.004	-0.003	-0.003	-0.003	-0.004	-0.0015
Implied Impact as % of Mean Equip Share	-3.0	-2.8	-2.3	-2.7	-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 normalized by the average of that attribute across all plants in the same industry in 1992. 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 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 plant attribute used in each column, its mean across plants in 1992, the mean equipment 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

We run a similar set of regressions for both the total and structure investment shares, as well as for establishments' log capital stock. The DID coefficients from these regressions are summarized in Figures 5 and 6. (Full results are not reported, but available). The first of these figures plots the main difference-in-difference 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

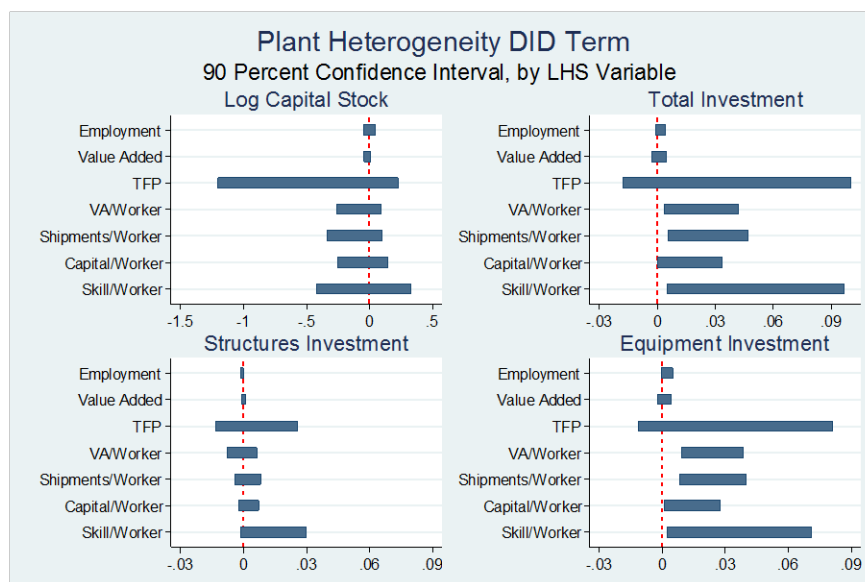
seven plant heterogeneity attributes we examine. The bottom right panel of this figure corresponds to the first row of Table 5. As noted in the figure, the main DID terms are negative for log capital (upper left panel) and for the total (upper right panel) and equipment investment (lower right panel) 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.



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 5) 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 5: Main DID Coefficients for CM Regressions

Figure 6 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 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.



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 5) 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 6: Plant Heterogeneity DID Coefficients for CM Regressions

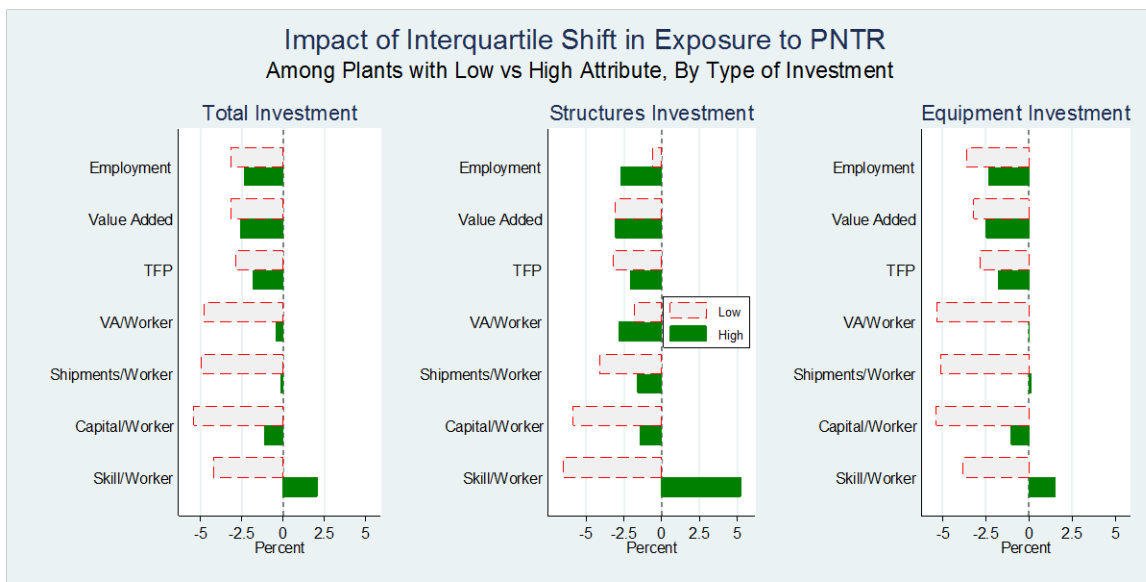
Finally, Figure 7 uses the coefficients reported in Figures 5 and 6, as well as information about the distribution of plants' attributes in 1992, to quantify how the economic impact of PNTR varies across establishments with different levels of a particular attribute. In the figure, each pair of bars 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.<sup>9</sup>

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.

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

<sup>9</sup>We plan to report standard errors for these implied impacts in a future draft.

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 7 is that plants with the highest skill intensity actually experience a relative increase equipment investment after the change in trade policy versus before.



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 5) 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 7: Implied Impact of PNTR With Plant Heterogeneity From CM Regressions

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 Van Reenen (2016). Alternatively, it could reflect capital expenditures used to upgrade product quality (Schott 2003, 2004) or switch production (Bernard, Redding and Schott 2011, Khandelwal 2014) towards goods more in line with U.S. comparative advantage.

## 4.2 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.<sup>10</sup>

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 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:

$$\begin{aligned} \ln(y_{pc}) = & \theta Post PNTR_c \times NTRGap_j + \\ & \beta \mathbf{X}_{jc} + \gamma Post PNTR_c \times \mathbf{X}_j + \\ & \delta_p + \delta_c + \alpha + \varepsilon_{pc}, \end{aligned} \tag{8}$$

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<sup>10</sup>Empirically, Bloom et al. (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.

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 8, time-varying control variables are averaged over each period.

	$\ln(SD_{pc}^{Total})$	$\ln(Avg_{pc}^{Total})$	$\ln(YrsPos_{pc}^{Total})$	$\ln(SD_{pc}^{Struct})$	$\ln(Avg_{pc}^{Struct})$	$\ln(YrsPos_{pc}^{Struct})$	$\ln(SD_{pc}^{Equip})$	$\ln(Avg_{pc}^{Equip})$	$\ln(YrsPos_{pc}^{Equip})$
Post x NTR Gap <sub>j</sub>	-0.362	-0.265	0.005	-0.355	-0.191	0.005	-0.935	-0.892	-0.179
	0.332	0.270	0.010	0.320	0.267	0.013	0.528	0.573	0.207
Post x $\ln(K/Emp_{j,1990})$	-0.141	-0.126	0.002	-0.192	-0.158	0.002	0.003	-0.031	-0.004
	0.083	0.077	0.002	0.078	0.073	0.002	0.115	0.106	0.026
Post x $\ln(NP/Emp_{j,1990})$	0.348	0.368	-0.002	0.348	0.391	0.008	0.246	0.174	0.017
	0.098	0.095	0.004	0.105	0.097	0.009	0.129	0.128	0.047
Post x Contract Intensity <sub>j</sub>	0.331	0.053	0.014	0.163	-0.044	0.017	0.869	0.727	0.067
	0.357	0.377	0.011	0.333	0.357	0.010	0.565	0.519	0.109
Post x DChina Subsidies <sub>j</sub>	56.457	52.119	-1.069	59.209	54.702	-1.396	5.503	6.610	1.624
	15.493	11.788	0.564	14.666	11.607	0.731	23.366	23.969	9.441
Post x DChina Licensing <sub>j</sub>	0.331	0.053	0.014	0.163	-0.044	0.017	0.869	0.727	0.067
	0.357	0.377	0.011	0.333	0.357	0.010	0.565	0.519	0.109
Post x 1{Advanced Technology <sub>j</sub> }	0.083	0.159	0.000	0.106	0.165	-0.008	0.113	0.123	0.006
	0.085	0.101	0.006	0.095	0.098	0.010	0.144	0.150	0.051
Post x Union Membership <sub>j</sub>	-0.0031	0.0013	0.0000	-0.0019	0.0022	-0.0002	-0.0069	-0.0090	-0.0027
	0.0038	0.0025	0.0001	0.0035	0.0025	0.0001	0.0046	0.0046	0.0026
MFA Exposure <sub>jc</sub>	-0.011	-0.014	0.001	-0.016	-0.017	0.002	-0.010	-0.028	-0.019
	0.011	0.012	0.001	0.012	0.013	0.002	0.015	0.015	0.006
NTR <sub>jc</sub>	-1.626	0.435	0.079	-1.086	0.670	0.099	-1.469	-0.152	1.443
	1.728	0.908	0.059	1.485	0.830	0.083	2.306	1.811	0.901
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	0.91	0.95	0.54	0.81	0.84	0.67
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 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 in Section 4.1, Table 6 sets a baseline by reporting coefficient estimates and standard errors from estimating equation 8 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.

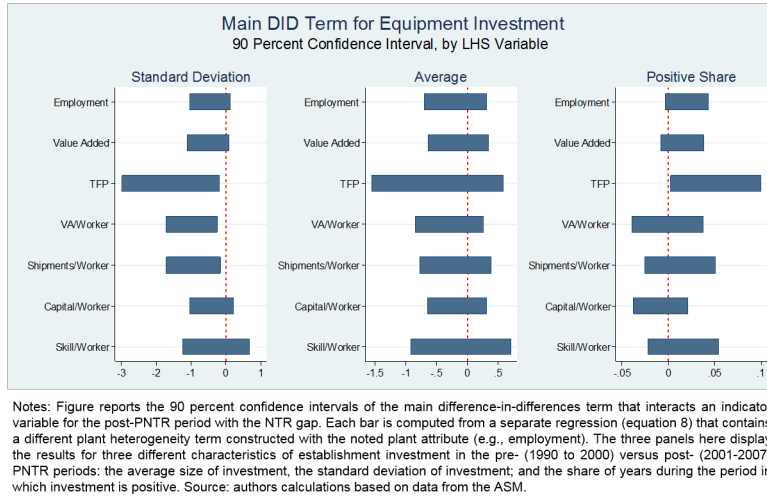
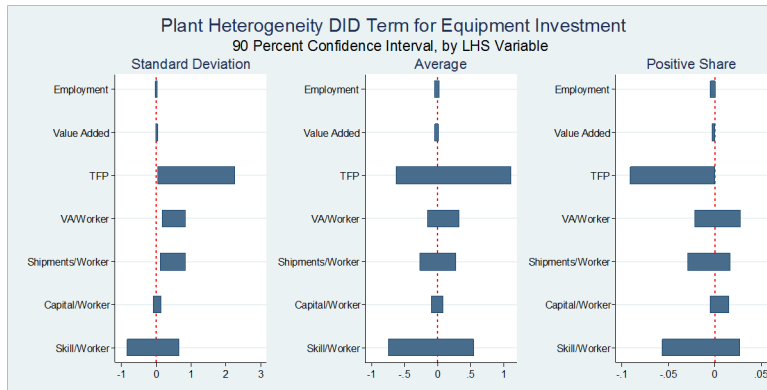


Figure 8: Main DID Coefficients for ASM Regressions

As above, when we augment equation 8 with plant heterogeneity terms, these relationships become clearer. Results from this augmented specification are displayed in Figures 8 and 9, which take the same format as Figures 55 and 6. 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.



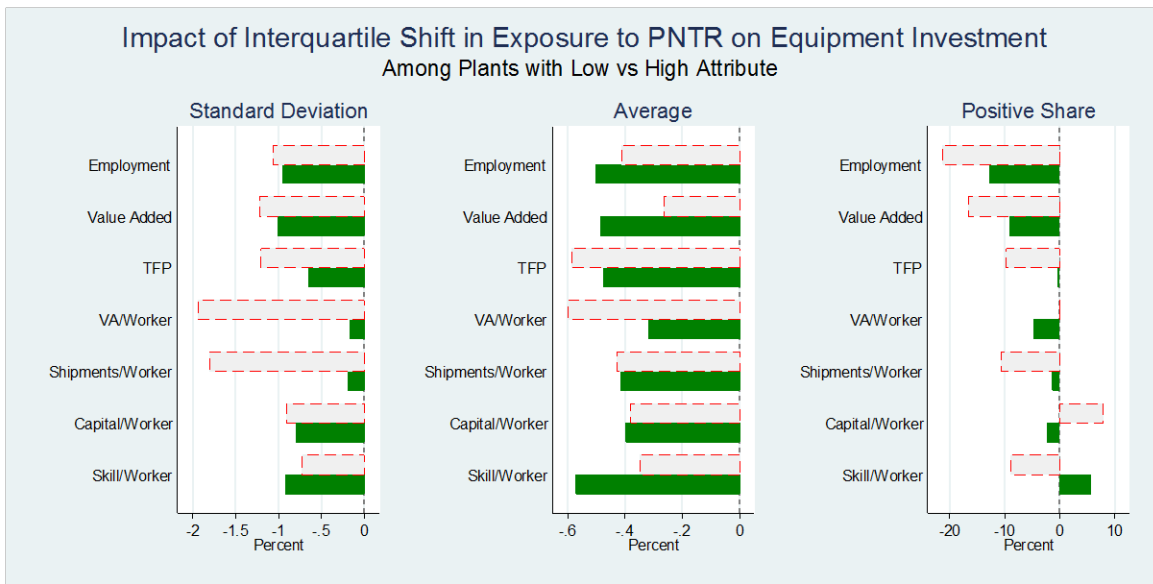
Notes: Figure reports the 90 percent confidence intervals of the plant heterogeneity difference-in-differences term that interacts an indicator variable for the post-PNTR period with the NTR gap and the noted plant attribute (e.g., employment). Each bar is computed from a separate regression (equation 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 9: Plant Heterogeneity DID Coefficients for ASM Regressions

Figure 8 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 for the CM, above, may reflect the select group of firms present in the balanced ASM sample.

Figure 9 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.





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 10: Implied Impact of PNTR With Plant Heterogeneity from ASM Regressions

As in the previous section, we combine the estimates plotted in in Figures 8 and 9 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 10. 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 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 for structures. 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 heterogenous responses of individual plants.

## References

- [1] Autor, David H., David Dorn and Gordon H. Hanson. 2013. "The China Syndrome: Local Labor Market Effects of Import Competition in the United States." *American Economic Review* 103(6): 2121-68.
- [2] Autor, David H., David Dorn, Gordon H. Hanson and Jae Song. 2014. "Trade Adjustment: Worker Level Evidence." *Quarterly Journal of Economics* 129(4): 1799-1860.
- [3] Autor, David H., David Dorn and Gordon H. Hanson. 2015. "The Labor Market and the Marriage Market: How Adverse Employment Shocks Affect Marriage, Fertility, and Children's Living Circumstances." Unpublished working paper at <http://economics.mit.edu/files/11562>.
- [4] Autor, David H., David Dorn, Gordon H. Hanson, Gary Pisano and Pian Shu. 2016. "Foreign Competition and Domestic Innovation: Evidence from U.S. Patents." Unpublished working paper at <http://economics.mit.edu/files/11708>.
- [5] Bai, Xue, Kala Krishna and Hong Ma. 2015. How You Export Matters: Export Mode, Learning and Productivity in China." NBER Working Paper 21164.
- [6] Becker, Randy, Wayne Gray and Jordan Marvakov. 2016. "NBER-CES Manufacturing Industry Database." Dataset available at <http://www.nber.org/nberces/>.
- [7] Bernard, Andrew, Stephen Redding and Peter K. Schott. 2011. "Multi-Product Firms and Trade Liberalization." *Quarterly Journal of Economics* 126(3): 1271-1318
- [8] Bloom, Nicholas, Mirko Draca and John Van Reenen. 2016. "Trade Induced Technical Change? The Impact of Chinese Imports on Innovation, IT and Productivity." *Review of Economic Studies* 83: 87-117.
- [9] Bloom, Nick, Stephen Bond and John Van Reenen. 2007. "Uncertainty and Investment Dynamics." *Review of Economic Studies* 74(2007): 391-415.
- [10] Brandt, Loren, Johannes Van Biesebroeck, Luhang Wang and Yifan Wang. 2012. "WTO Accession and Performance of Chinese Manufacturing Firms." Centre for Economic Policy Research Working Paper 9166.
- [11] Gutierrez, German and Thomas Philippon. 2017. "Declining Competition and Investment in the U.S." Unpublished working paper at [https://www8.gsb.columbia.edu/faculty-research/sites/faculty-research/files/finance/Macro%20Lunch/IK\\_Comp\\_v1.pdf](https://www8.gsb.columbia.edu/faculty-research/sites/faculty-research/files/finance/Macro%20Lunch/IK_Comp_v1.pdf).
- [12] Handley, Kyle. 2014. "Exporting Under Trade Policy Uncertainty: Theory and Evidence." *Journal of International Economics* 94(1): 50-66.

- [13] Heise, Sebastian, Justin R. Pierce, Georg Schaur and Peter K. Schott. 2017. Trade Policy and the Structure of Supply Chains. Unpublished manuscript.
- [14] Hirsch, Barry T. and David A. Macpherson. 2003. "Union Membership and Coverage Database for the Current Population Survey." *Industrial and Labor Relations Review* 56 (2): 349-54.
- [15] Kurz, Christopher J., and Norman J. Morin (2016). "Annual data on Investment and Capital Stocks," FEDS Notes. Washington: Board of Governors of the Federal Reserve System, <http://dx.doi.org/10.17016/2380-7172.1717>.
- [16] Khandelwal, Amit K., Peter K. Schott and Shang-Jin Wei. 2013. "Trade Liberalization and Embedded Institutional Reform: Evidence from Chinese Exporters." *American Economic Review* 103(6): 2169-2195.
- [17] Nunn, Nathan. 2007. "Relationship-Specificity, Incomplete Contracts and the Pattern of Trade." *Quarterly Journal of Economics* 122 (2) 569-600.
- [18] Pierce, Justin R. and Peter K. Schott. 2012. "Concording U.S. Harmonized System Codes Over Time." *Journal of Official Statistics* 28(1): 53-68.
- [19] Pierce, Justin R. and Peter K. Schott. 2016a. "The Surprisingly Swift Decline of U.S. Manufacturing Employment." NBER Working Paper 18655.
- [20] Pierce, Justin R. and Peter K. Schott. 2016b. "Trade Liberalization and Mortality: Evidence from U.S. Counties." NBER Working Paper 22849.
- [21] Pindyck, Robert S. 1993. "Investments of Uncertain Cost." *Journal of Financial Economics* 34 (1): 53-76.
- [22] Rob, Rafael and Nikolaos Vettas. 2003. "Foreign Direct Investment and Exports with Growing Demand." *Review of Economic Studies* 70(3): 629-648.
- [23] Schwartz, Eduardo S. and Carlos Zozaya-Gorostiza. 2003. "Investment Under Uncertainty in Information Technology: Acquisition and Development Projects." *Management Science* 49 (1): 57-70.
- [24] Schott, Peter K. 2003. "One Size Fits All? Heckscher-Ohlin Specialization in Global Production." *American Economic Review* 93(2): 686-708.
- [25] Schott, Peter K. 2004. "Across-Product Versus Within-Product Specialization in International Trade." *Quarterly Journal of Economics* 119(2): 647-678.