

Labor-induced Technological Change: Evidence from Doing Business in China

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Abstract

We study how the change in the price of labor affects the direction of technological change using a novel measure decomposing innovations into products (new goods) and processes (lower production cost). Using the 1999 U.S.-China bilateral agreement as a shock that lowered effective labor cost, we find that U.S. firms operating in China decrease their process to total innovations ratio by 9% and that this adjustment is driven by lower process innovation. We obtain the same results using a staggered loosening of restrictions on foreign ownership across industries in China over 1995-2012. This evidence suggests that cheap abundant labor substitutes for labor-saving technological innovation.

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Manufacturers who had been automating U.S. and European factories to shave labor costs stopped once they set up in China. “Machines couldn’t compete”, says David Love, a Levi executive vice president. As late as 2002, Chinese labor costs were just 60 cents an hour, according to the Conference Board, a business research group. (WSJ, 11/23/2015)

I Introduction

One of the central questions of economic growth is how labor scarcity and high wages alter the direction of technological change and whether they encourage technological advances. Basic intuition suggests that if a production factor becomes more expensive, the demand for it decreases, and some of this adjustment takes place by technology substituting for tasks performed by this factor, which then induces innovation more broadly.¹ For example, according to Habakkuk (1962), it was the scarcity of labor in the nineteenth century United States that obliged American manufacturers to install new types of labor-saving machinery, as compared to British manufacturers, and led to the future continuous progress of American industry. In contrast, according to many canonical macroeconomic models, when new technologies are embodied in capital goods, labor scarcity and high wages slow down technological progress. Theoretical predictions are in fact ambiguous: Acemoglu (2007) shows that an increase in the abundance of a production factor can make the technology relatively biased toward or against this factor, while Acemoglu (2010) shows that labor scarcity may induce or discourage technological progress depending on the nature of technology.

In this paper, we examine how the change in the price of labor affects the direction of technological change, focusing on the two main types of innovation: product and process.² Product innovation results in new goods while process innovation refers to new methods

¹In *The Theory of Wages*, John Hicks argues: “a change in the relative prices of the factors of production is itself a spur to invention, and to invention of a particular kind—directed to economizing the use of a factor which has become relatively expensive” (1932, p. 124).

²We delineate product and process innovations by classifying firms’ patent claims into product and process claims. To classify the claims, we parse the structured-text documents of the universe of patent grants issued by the United States Patent and Trademark Office.

that lower production cost (Scherer 1982, 1984; Link, 1982; Eswaran and Galini, 1996). Specifically, we ask whether and how U.S. firms changed their process-product innovation mix in response to a decrease in their effective labor cost driven by improved ability to harness cheap and abundant Chinese labor. Our key argument is that U.S. firms consider two alternative ways to lower their production cost: substituting Chinese for U.S. labor and investing in process innovation. Our hypothesis is that, when Chinese labor becomes more attractive, the return on investment in process innovation relatively decreases, which makes the U.S. firms invest less in process innovation. We document that, in response to lower effective labor cost, U.S. firms operating in China change their process-product innovation mix by pursuing less process innovation.

A major benefit of operating in China for U.S. firms is a large supply of low-cost labor. Average Chinese factory-worker hourly wages were 3% of the corresponding U.S. wages in the 2000s.³ However, U.S. firms operating in China cannot capture the benefit of low wages because Chinese partners (for example, joint venture counterparts, suppliers, distributors) capture a large share of the profits of U.S. firms' subsidiaries in China.⁴ As a result, the effective labor cost of U.S. firms from their Chinese operations does not only depend on the wage paid to Chinese workers, but also on the share of profits of Chinese subsidiaries that is captured by the Chinese partners.

To identify an exogenous change in U.S. firms' labor cost, we rely on the *1999 U.S.-China bilateral agreement* which decreased effective labor cost of U.S. firms operating in China. The agreement, which was largely unanticipated due to the turbulent political landscape, lifted U.S. firms' restrictions on doing business in China, such as: the removal of

³"China's average manufacturing wages, at about \$0.25 per hour, are about one-fifth as great as Mexico's, and about one-fiftieth as much as total compensation for manufacturing workers in the United States. China's labor force is 18 times that of Mexico and five times that of the United States" (CSR Report for Congress, 2000).

⁴The idea that China is a prominent example of hold-up problems due to the fact that foreign companies have to deal with local partners is not new. In *Poorly Made in China*, Midler (2009) describes how Chinese suppliers extract surplus from Western companies by manipulating prices and quality and argues that solutions like relationship contracting were not effective in the case of China. See also discussion in Antràs (2003, 2005, 2013).

local content and export performance requirements, the withdrawal of FDI's approval being conditional on the usage of domestic suppliers, or the liberalization of distribution services. While a large share of the profits of Chinese subsidiaries accrued to Chinese partners before 1999, the agreement increased the share of the profits the U.S. firms capture post-1999, effectively reducing their labor costs. In our analysis, we therefore compare the effect of the *1999 U.S.-China bilateral agreement* on U.S. high-patenting firms with a subsidiary in China prior to the agreement (treated) relative to U.S. high-patenting firms with no such presence (control).

We find that, after 1999, the treated firms have a lower share of process to total innovations relative to the control firms by 3 percentage points compared to pre-treatment years, which is a 9% reduction relative to the median ratio. We show that this change in the process-product innovation mix is driven by a lower level of process innovation, which is 19% lower for the treated firms. In contrast, the agreement has no differential effect on the level of product innovation of the treated relative to control firms.⁵ These results suggest that cheap Chinese labor decreases return to investing in labor-saving technological innovation, namely innovation substituting for more “expensive” U.S. workers.

To provide support for the economic mechanism we consider, we examine subgroups where we expect to observe differential treatment effects. First, we exploit cross-sectional variation in the equity shares of U.S. firms vis-à-vis their Chinese counterparts in the Chinese subsidiaries. Since the effect we are identifying operates through the ability of U.S. firms to capture a higher share of the subsidiaries' profits, we expect the treated firms with higher U.S. equity relative to Chinese equity to respond more to the agreement. As predicted, we find a larger negative effect on the process-product innovation mix and the level of process innovation for such treated firms. Second, consistent with the intuition that our findings are due to the labor channel, we find that the treatment effect is smaller when the subsidiaries of the U.S. firms in China expect to pay relatively higher wage bills.

⁵This evidence suggests that the U.S. firms with presence in China do not increase the rate of product innovation by more due to an improved access to the Chinese large and rapidly developing market (Utterback and Abernathy, 1975; Klepper, 1996; Mitchell and Skrzypacz, 2011).

To proxy for higher expected wage bills, we require the subsidiary to be located in Chinese counties with the growth rate of minimum wages in 1998 above the sample median and also the number of workers employed by the subsidiary to be above the sample median.

In our regressions, we control for time-invariant firm characteristics, by including firm fixed effects, for time-varying firm characteristics, by including firm-level controls, and for time-varying industry characteristics, by including interacted industry and year fixed effects. Our key identifying assumption is that, conditional on these controls, the assignment of firms into the treated and control group is “as good as random.” We conduct several analyses to show support for this assumption. First, we compare summary statistics of firm characteristics for our treated and control samples in 1998 and show that there are no systematic differences pre-treatment. Second, we find no significant effect of the agreement in pre-treatment years, while the effect persists after the shock. Third, when we control for potential differential trends between the treated and control firms by interacting the value of the dependent variable in 1998 with a full set of year dummies, our results continue to hold. These results suggest that there are no pre-trends in our data. We also repeat our analyses using a matched control sample and obtain very similar results.

In our robustness checks, we sort firms into placebo treated and control groups based on whether they have a subsidiary in Asia excluding China in 1998, adding a placebo interaction term to our regressions. If our results are driven by an omitted variable, such as productivity shocks that are common to countries in similar geographies, we should observe a negative and significant coefficient on the placebo interaction term, but we do not. Another potential concern is that we are capturing the effect of Chinese import competition on technological change. Bloom, Draka, and Van Reenen (2015) find a positive effect of Chinese import competition on the level of innovation of European firms. To the extent that our treated and control firms might be differentially affected by import competition, it is possible that a response to Chinese imports is driving our results. To address this concern, we show that Chinese import competition has no differential effect on the process-product innovation mix and on the levels of process and product innovations.

To further establish causality, we examine whether our results are robust to using an alternative setting. We use the variation across industries and over time in ownership restrictions imposed on foreign investments by the Chinese government. The source of this information is the Foreign Investment Industry Catalogues issued six times in the 1995-2012 period. Similar to our main experiment, the staggered loosening of restrictions on foreign ownership implied by the catalogues changes the split of the profits of Chinese subsidiaries in favor of U.S. firms, effectively reducing labor cost. We find that the loosening of restrictions decreases the ratio of process to total innovations and the level of process innovation for high-patenting firms with subsidiaries in China as compared to those with no interest in China, while there is no differential effect on the level of product innovation.

Our paper is related to prior studies that analyze the effect of trade between low-wage and developed countries on various outcomes of import-impacted firms, such as employment and wages (Autor, Dorn, and Hanson, 2013; Acemoglu, Autor, Dorn, and Hanson, 2014; Pierce and Schott, 2015), innovation (Bloom, Draka, and Van Reenen, 2015), performance and survival (Bernard, Jensen, and Schott, 2006; Hombert and Matray, 2015), cost of debt (Valta, 2012), and capital investment (Frésard and Valta, 2015). China garners significant attention in this literature due to its size and rapid trade growth. Also related is the literature on the impact of regulatory frictions on international trade and investment. Moran (2001) studies the effects of domestic-content, joint-venture, and technology-sharing requirements on production transfer to developing countries. Desai, Foley, and Hines (2004) find that when ownership restrictions are lifted, intra-firm trade and technology transfer of U.S. multinationals increase. Antràs (2005) formalizes this idea and shows that the trade-off between a lower production cost and contract incompleteness in international transactions limits the fragmentation of the production process, leading to less new products being produced in low-production cost countries. We add to these literatures by studying an unexplored issue—how the increasing availability of China’s cheap labor for global production affects technological choices of firms in developed countries.

There is also a limited number of empirical studies examining the relation between production factors and the adoption of existing technologies (Acemoglu and Finkelstein,

2008) or development of new technologies (Newell, Jaffe, and Stavins, 1999; Hanlon, 2015). Acemoglu and Finkelstein (2008) show how regulatory changes in the U.S. healthcare sector affect the capital-labor mix and technology adoption in hospitals. Newell et al. (1999) look at the effect of energy prices on the direction of innovation. Hanlon (2015) studies the response of technology to a change in the type of cotton used in the British cotton textile industry due to the U.S. Civil War and finds that an increase in the supply of Indian cotton induced technological changes that augmented Indian cotton. Our study shows that the price of labor is an economically important determinant of the process-product innovation mix, which is consistent with the view that changes in the relative prices of the factors of production drive the direction of technological change.

The remainder of the paper is organized as follows. Section II describes our measures of the direction of technological change. Section III gives details on the 1999 U.S.-China bilateral agreement. In section IV, we present the main identification approach using the 1999 U.S.-China agreement to study the effect of labor cost on the direction of technological change. Section V presents the alternative experiment, and section VI concludes.

II Data and Construction of Variables

We measure firms' technological choices by looking at their process-product innovation mix. By definition, a process innovation describes a new way to produce the same good, while a product innovation describes a new good that did not exist before. Prior literature argues that a process innovation is aimed at improving a firm's own production methods in order to lower its production cost, while a product innovation is an improvement sold to others—either to other firms or to final consumers (Scherer 1982, 1984; Link 1982; Cohen and Klepper, 1996; Eswaran and Gallini, 1996).

To proxy for firms' process and product innovations, we examine the output of corporate R&D activities as measured by patents, the exclusive rights over an invention of a product or a process (Griliches, 1990). We collect information from the complete set of patent grant publications issued weekly by the United States Patent and Trademark Office (USPTO)

from January 1990 to June 2013.⁶ In this way, we obtain full texts of the universe of utility patents awarded by USPTO to U.S. and international companies, individuals, and other institutions. We parse the structured-texts of patent grants to first identify the section that contains patent claims, and next to classify each claim within this section as process or product. We are also able to classify claims into independent or dependent.⁷ Patent claims define—in technical terms—the scope of protection conferred by a patent, and thus define which subject matter the patent protects. Claims are critical defining elements of a patent and are the primary subject of examination in patent prosecution. Claims are also crucial in patent litigation cases.

To measure a firm’s process-product innovation mix, we define *Share of process innovations*_{it} as the ratio of the number of process claims to the total number of claims that are contained in patents applied for by firm *i* in year *t*. Alternatively, we use *Share of process innovations_Independent*_{it} defined analogously using independent claims only. To measure the quantity of process (product) innovation output, we define *Process innovations*_{it} (*Product innovations*_{it}) as the natural logarithm of one plus the number of process (product) claims that are contained in patents applied for by firm *i* in year *t*. Alternatively, we use *Process innovations_Independent*_{it} and *Product innovations_Independent*_{it} that are based on counts of independent process and product claims, respectively.

We also classify each patent as: i) a process patent, if all patent’s claims are process claims; ii) a product patent, if all patent’s claims are product claims; iii) a process-apparatus patent, if the first patent’s claim is a process claim and there exists at least one independent claim that is a product claim; iv) a product-method patent, if the first patent’s claim is a product claim and there exists at least one independent claim that is a process claim. At patent level, our measure of a firm’s process-product innovation mix is *Share of process innovations_Patent*_{it} defined as the sum of the number of process and process-apparatus patents (or, alternatively, the sum of the number of process, process-apparatus,

⁶We download the publications from the ‘United States Patent and Trademark Office Bulk Downloads’ page hosted by Google Inc. at <http://www.google.com/googlebooks/uspto.html>.

⁷A detailed description of how we distinguish claim types is provided in Appendix A.

and product-method patents) divided by the total number of patents applied for by firm i in year t . Using this definition, we classify tools and apparatuses that are patented together with process claims in the same patent as process innovations. In Appendix A, we provide summary statistics and validation checks for our innovation variables.

To assign patents to firms in Compustat, for each patent, we identify patent assignees listed on the patent grant document, the country of these assignees, and the indicator of whether each assignee is a U.S. corporation, a non-U.S. corporation, an individual, or a government body. Using this information, we match patents to firms in Compustat. Our matching algorithm involves two main steps. First, we standardize patent assignee names and firm names—focusing on unifying suffices and dampening the non-informative parts of firm names. Second, we apply multiple fuzzy string matching techniques to identify the firm, if any, to which each patent belongs.⁸

III 1999 U.S.-China Bilateral Agreement

The bilateral agreement signed between the U.S. and China in November 1999 was a landmark in the economic relations of the two countries and it paved the way to China’s entry into the World Trade Organization (WTO). This agreement involved significant concessions from China, including tariff reductions, trade barrier removals, and the elimination of a number of restrictions on investment by U.S. firms.

The agreement was unexpected due to turbulent political relations between the two countries. Figure B1 in Appendix B presents the timeline of the events leading to the agreement (see Devereaux and Lawrence (2004) for a detailed description of the events). In mid-1997, the U.S. puts aside multilateral negotiations and starts bilateral talks with China—a decision driven mainly by political reasons. In 1998, little progress is being made. A milestone in the talks is the visit of Premier Zhu Rongji in the U.S. in April 1999, when

⁸See Bena, Ferreira, Matos, and Pires (2015) for a more complete description of the matching procedure and a comparison of the matches to those in the NBER patent database. Note that the NBER patent database provides GVKEY-patent number links for patents awarded till 2006, while our matching is based on patents awarded till June 2013.

he made, *for the first time*, significant concessions. These concessions galvanized U.S. firms to start unprecedented lobbying for the agreement, as they now realized its benefits. No agreement was signed however, and the negotiations were seriously threatened a few weeks later when U.S. mistakenly bombed the Chinese embassy in Belgrade. The agreement was finally signed on November 15, 1999 when the U.S. Trade Representative (USTR) Charlene Barshefsky visited China. To emphasize the uncertainty surrounding the negotiations, it is worth mentioning that USTR threatened to leave China three times and the negotiations were completed only after she decided to stop at the trade ministry on her way to the airport.

Historically, U.S. firms operating in China faced numerous restrictions and government interventions that were substantially alleviated by the newly signed agreement. Specifically, China lifted ownership restrictions on foreign investment and agreed to comply with the WTO Trade Related Investment Measures agreement upon accession. China also ceased to impose trade and foreign exchange balancing requirements, local content requirements (which require foreign firms to use domestic materials and parts for production), and export performance requirements (which require the export of a specified percentage of production volume). China committed that approval of investment will not be conditioned on whether domestic suppliers of such products exist, or requirements of any kind such as offsets, transfer of technology, production processes, or the conduct of research and development in China. The terms and conditions of any such transfers will be agreed between the parties to the investment without government interference. Furthermore, China committed to ensure fair competition between private and state-invested enterprises and liberalize distribution services, allowing foreign firms to set up wholly-owned distribution, sales, shipping, and service networks. Overall, the agreement secured that China is moving toward “rule of law” and will be held accountable for the contracts that it makes (Charlene Barshefsky, 18 November 1999).

IV Empirical Strategy

IV.1 Sample construction and summary statistics

To construct our sample, we hand-collect information on which U.S. firms have subsidiaries in China as of 1998, i.e., the year prior to the U.S.-China bilateral agreement is signed. To do so, we start from Compustat firms that are matched to our innovation variables and we require that: i) they have non-missing assets in Compustat for four years around the event-year, i.e. between 1998 and 2001, and they have applied for a minimum of twenty patents in the four-year period between 1998-2001, ii) they do not exit the sample immediately after the event, i.e. assets are reported in Compustat for a three-year period after the event. These filters ensure that we hand-collect information for a reasonable sample of firms that are active in performing innovation around the time of the event and do not exit the Compustat sample immediately after the event. We collect information on firms' subsidiaries in China from 10K filings. If 10K filing is not available for a given firm at the time of the event, the firm is dropped from the sample. The treated group consists of firms with a subsidiary in China as of 1998, i.e., prior to the U.S.-China bilateral agreement is signed in 1999. The control group consists of firms with no such presence in China.

Our main dependent variable $Share\ of\ process\ innovations_{i,t}$ is only defined for firm-years with at least one patent filing and it provides a meaningful measure of the changes in the process-product innovation mix only for firms with a nontrivial number of patents. Therefore, we include in our regressions intensely innovating Compustat firms, namely those that applied for 150 patents or more with the United States Patent and Trademark Office (USPTO) in the 1995-2004 period. In Table C1 of Appendix C, we show our results are robust to using different cutoffs for defining intensely patenting firms. This restriction is not necessary when we use quantities of product and process innovations as dependent variables. In Appendix C, we show that our results are robust to removing this restriction.

Table 1 provides summary statistics of our sample firms' patents. On average, a patent has 19.6 claims, of which 7.4 are process, 12.3 are product, 3.4 are independent, and 16.2

are dependent. A comparison with statistics in Table A1 shows, that a typical patent of our sample firms closely resembles a typical utility patent issued by USPTO. Table 2 provides summary statistics of our sample firms' characteristics. On average, a firm in our sample has assets of \$13.6 billion, sales of \$10.4 billion, profits of \$1.8 billion, and 36.8 thousand employees. It also holds \$1.3 billion in cash and \$2.5 billion in long-term debt, has capital expenditures of \$0.8 billion, has a market to book equity ratio of 4.5, and has sales growth of 9.6%. The majority of our sample firms are manufacturing firms (SIC 20-39, 84% of firms) followed by services (SIC 70-89, 10% of firms), while the remaining 6% of firms are evenly populated across the remaining industries.

We pick November 1999 as the date of the event. To establish causality, we need to argue that no omitted variable that predicts assignment into the treated or control group would also predict our outcome variables. In Table 2, we provide summary statistics separately for the treated and control firms computed in 1998, the year before the event. We compare treated and control groups using a t-test of differences in means across multiple dimensions, including size (assets, sales, and number of employees), investment opportunities (market to book ratio and sales growth), financing (cash, debt), and profits. We find no significant differences between the treated and control firms' characteristics, which suggests that treated and control firms are similar in terms of observable characteristics. In our empirical analysis, we perform further tests which address concerns that differences in treated and control groups are driving the results.

IV.2 Baseline results

To identify the effect of the price of labor on the process-product innovation mix, we employ a difference-in-differences approach. We estimate changes in the share of process innovations at firms with a presence in China prior to the agreement relative to firms without such presence, and whether the effect of having a presence in China is different following the 1999 U.S.-China bilateral agreement as compared to years before the agreement. We estimate regressions of the following form:

$$y_{i,t} = \alpha_t + \lambda_i + \delta \cdot \text{Agreement}_{(t>1999)} \cdot \text{China}_i + \beta \cdot X_{i,t-1} + \epsilon_{i,t}, \quad (1)$$

where i and t index firms and years; $y_{i,t}$ stands for *Share of process innovations* $s_{i,t}$, *Process innovations* $s_{i,t}$, or *Product innovations* $s_{i,t}$; $\text{Agreement}_{(t>1999)}$ is an indicator variable that takes a value of 1 for years post-1999; China_i is an indicator variable that takes a value of 1 for firms in our treated group, namely those that have a subsidiary in China as of 1998 according to their 10K filings (42% of firms in our sample belong to the treated group); $X_{i,t-1}$ are time-varying firm-level control variables lagged by one year; α_t and λ_i denote year and firm fixed effects, respectively; and $\epsilon_{i,t}$ is the error term. Coefficient δ captures the change in the process-product innovation mix at firms with a presence in China as of 1998 following the 1999 U.S.-China bilateral agreement as compared to years before the agreement, relative to firms without such presence.⁹ We start our sample in 1995 to provide sufficient years to estimate baseline shares of process innovations for each firm and end in 2004, thereby using 10 years of data around the event. All variables are winsorized at the 1% level. Standard errors are clustered at the firm level.

Table 3 presents estimates of regression (1) with *Share of process innovations* $s_{i,t}$ as the dependent variable. The specification in Column 1, that does not include any firm-level control variables, shows that the treated firms lowered the share of process innovations relative to control firms post-1999 by 3 percentage points compared to pre-treatment years, which is a 9% reduction relative to the median ratio in the sample. The coefficient is significant at 1% level. In Column 2, we additionally control for time-varying firm-level controls, namely the natural logarithm of firm sales (as a proxy for size) and market to book ratio (as a proxy for investment opportunities).¹⁰ In Column 3, we add interacted year and two-digit SIC industry fixed effects to the specification in Column 2 to account

⁹Variables $\text{Agreement}_{(t>1999)}$ and China_i are absorbed by the fixed effects and their coefficients are thus not estimated.

¹⁰Cohen and Klepper (1996) examine the effect of firm size on the allocation of R&D effort between process and product innovation and find evidence that process R&D undertaken by firms rises with firm size.

for time-varying industry effects such as changes in investment opportunities. In both specifications, the coefficient δ is statistically significant at the 1% level. The fact that the additional controls have little impact on the results suggests that our results are not driven by differences in size, investment opportunities, or industry trends between the two groups.

In the baseline estimates, the identification comes from the comparison of changes in the share of process innovations by firms affected by the agreement (treated firms) with those by firms that are not affected by the agreement (control firms). A possible concern is that the estimated treatment effect could be attributed to differential trends in pre-treatment firm characteristics, because our $China_i$ variable is not randomly assigned. To address this concern, we follow Acemoglu and Finkelstein (2008) and include the interaction term between $China_i$ and an indicator variable that takes a value of 1 in year 1999 into our Column 3 specification. The coefficient on this interaction term captures possible differential trends in the share of process innovations between treated and control firms. The result, reported in Column 4, shows that the coefficient δ remains unchanged and the coefficient on the new term is positive, small in magnitude, and not statistically significant. This evidence suggest that the treated and control firms did not have different shares of process innovations pre-treatment.

In Column 5, we estimate a further augmented version of equation (1) where we interact $China_i$ with an indicator variable for each year t . We omit the 1996 interaction term and thus set 1996 as the baseline year (note that year 1995 is dropped because we lag the control variables). We find that no interaction term is significant pre-treatment, while the coefficients for the years following the agreement are all negative and statistically significant at the 5% level. The effect we estimate is significant in 2000, the year after the event, its magnitude increases from 2000 to 2001, and it remains fairly stable through 2004. This evidence is consistent with findings in the literature that there is no lag between R&D expenditure and patenting, but rather a contemporaneous relationship (Hausman, Hall, and Griliches, 1984; Hall, Griliches, and Hausman, 1986).

A related concern might be that treated firms' shares of process innovations mean-revert

to some firm-specific equilibrium level post 1999, which is captured by our interaction term. To address this concern, we interact the value of the dependent variable in 1998 (Column 6) and the value of the number of patents (log-transformed) in 1998 (Column 7) with a full set of year dummies, and add these interaction terms to the Column 4 specification. Coefficient δ remains almost identical in both cases, which shows that mean reversion or differential trends based on pre-treatment innovation characteristics do not impact our results.

Since entry in China is likely to respond endogenously to the agreement, we define $China_i$ in 1998 – the year before the agreement is signed – throughout our baseline analysis. To the extent that all U.S. firms with a presence in China, including those that entered China after 1998, would also benefit from the agreement, we re-estimate our baseline regressions using a time-varying measure of treatment. To this end, we construct an indicator variable $China_{i,t}$ that takes a value of 1 if a firm has a subsidiary in China in a given year t according to its 10K filings (18% of our control firms enter China in 1999 or later), and use it in the interaction with $Agreement_{(t>1999)}$. We report the results in Table C2 of Appendix C. The coefficient on the interaction term is negative and significant at the 1% level. Its magnitude indicates a 4 percentage points reduction in the share of process innovations, which is a 12% reduction relative to the median ratio in the sample. Moreover, we estimate an augmented specification where we interact an indicator for each year (d_t) with the $China_{it}$ dummy. We confirm that there are no pre-treatment differences, while the effect is negative and significant from 2000 and until 2004, the end of our sample.

IV.3 More product or less process innovation?

The reduction in the ratio of process to total innovations we document may be due to less process innovations, more product innovations, or process and product innovations changing at different rates. To the extent that firms have less incentives to economize on the use of labor because the 1999 U.S.-China bilateral agreement reduced U.S. firms' *effective* wage costs from Chinese operations, we should find that a lower share of process innovations we document above is due to less process innovations. Alternative channels though could be

also at work. It is possible, for example, that a lower share of process innovations is due to more product innovations driven by firms' needs to introduce new variations of their products as they are gaining a better access to the Chinese market. This prediction stems from theories of industry evolution as pioneered by Utterback and Abernathy (1975).¹¹

To distinguish these two possibilities, Table 4 examines the effect of the agreement on the quantities of process and product innovations separately. In Columns 1-4, the dependent variable is *Process innovations_{it}* and in Columns 5-8 the dependent variable is *Product innovations_{it}*. Columns 1 and 5 include no controls, Columns 2 and 6 control for the overall intensity of firms' innovation activities using the number of patents filed by each firm-year, and Columns 3-4 and 5-6 additionally control for firm size and market to book ratio. All columns include firm and year fixed effects, while Columns 4 and 8 additionally control for interacted year and two-digit SIC industry fixed effects.

We find that the quantity of process innovations decreases after the agreement. The coefficient δ , significant at 1% level across specifications, shows a 19% reduction in the number of process claims (Column 4). On the contrary, the coefficients on the quantity of product innovations are neither statistically nor economically significant.¹² These results provide support for the "access to cheap Chinese labor" explanation. Multinational Monitor comments on the agreement: "*U.S. businesses want the right to exploit its (China's) cheap labor, or at least to import goods made in China with cheap labor*".¹³

U.S. firms invest in China to take advantage of lower labor cost. The hourly average factory-worker wage in China was \$0.5 in 2000 versus \$16.6 in the U.S. (a ratio of 0.03),

¹¹See also discussions by Klepper (1996), Mitchell and Skrzypacz (2011).

¹²These results are robust to: i) allowing for a time-varying measure of treatment using variable *China_{it}* (Table C3 in Appendix C), ii) dropping the requirement that firms in our sample are high-patenting (Table C4 in Appendix C), and iii) normalizing the quantities of process and product innovations by R&D expenditure or employment (Table C5 in Appendix C).

¹³Porter and Rivkin (2012) asked 10,000 Harvard alumni running businesses what are the main reasons for moving production out of the U.S. 70% of the respondents mention lower wage rates as the main reason for moving existing activities out of the U.S.. When the same respondents were asked which are the countries they consider transferring their production to, China was the most common response (42% of the answers).

while the same ratio is 0.04 in 2005, the final year in our sample.¹⁴ Prior to the agreement, U.S. firms had to work with Chinese partners (e.g. suppliers, distributors, government) and split the profits. This would lead to hold-up problems, disrupting firms' operations. China is a prominent example of hold-up problems due to the fact that foreign companies have to deal with local counterparties.¹⁵ Hold-up problems are often arising due to contact incompleteness, which is typically the case with international contracts (Rordik, 2000). The bilateral agreement expanded the space of applicable contracts, and in particular, allowed U.S. firms to side step, if necessary, working with Chinese partners. Thus, it increased the share of the profits accruing to U.S. firms, effectively reducing labor costs. Our results are consistent with the idea that access to cheaper Chinese labor reduces the return on investment in process innovations.

Our results may also be interpreted in light of the idea that lower uncertainty over input costs, following the 1999 U.S.-China agreement, eliminates firms' option value to delaying changes in their innovation mix (Pindyck, 1993).¹⁶

IV.4 Alternative explanations and robustness tests

In this section, we examine whether potential confounding effects are driving our results. First, we show that our results are not driven by unobserved economic shocks (e.g. technology, demand shocks). Second, we show our results are not driven by a response of U.S. firms to increasing Chinese import competition, or by U.S. export growth to low wage countries. Third, we perform key robustness tests, and show our results are robust.

¹⁴See Exhibit 1, in a Boston Consulting Group report: "Why manufacturing will return to the U.S".

¹⁵Antràs (2013) highlights the nature of incomplete contracts in China by citing a Chinese old saying: "signing a contract is simply a first step in negotiations".

¹⁶"U.S. companies expect to benefit from billions of dollars in new business and an end to years of uncertainty in which they had put off major decisions about investing in China. The business relationship has grown rapidly but remains lopsided, partly because of Chinese market restrictions and partly because of the vast discrepancy in wealth between the countries" (The New York Times, September 2000).

IV.4.1 Potential confounds: Economic shocks

We now examine whether unobserved economic shocks, e.g., demand, productivity, or technology shocks, affecting local economic conditions in China can be driving our results. To the extent that such shocks, unlike the terms of the agreement, spillover across neighboring geographies and drive our results, the process-product innovation mix of U.S. firms with subsidiaries in Asian countries other than China would spuriously appear to react to the agreement. To examine this possibility, we augment our baseline specification by including a placebo interaction between variable $Agreement_{(t>1999)}$ and an indicator variable which takes the value of 1 if a firm has a subsidiary in Asia but not in China ($Asia, NON-China_i$) as reported in the 10K filings in 1998 – a placebo treated group.

In Columns 1-2 of Table 5, we repeat specifications of Columns 2-3 in Table 3 and find that the coefficient on the interaction term with the placebo treated group is neither statistically nor economically significant, while the coefficient on the interaction term with the treated group remains negative, statistically significant, and, if anything, slightly larger in magnitude. Columns 3-4 repeat specifications in Columns 2-3 of Table 4 for process innovations and Columns 5-6 repeat specifications in Columns 5-6 of Table 4 for product innovations. We show that the coefficients on the placebo treated group interactions are small in terms of economic magnitude and not statistically significant, while our baseline results remain unchanged. Thus, regardless of the specification, we are unable to replicate our results for firms having presence in Asia (excluding China). These results address the concern that confounding factors, such as technology or productivity shocks in China, are driving the results.

IV.4.2 Trade with China

The international trade literature has documented that increases in import competition from low-wage countries impacts technical change. Specifically, a reduction in the relative profitability of making low-tech products due to cheaper Chinese imports gives U.S. firms stronger incentives to innovate new goods and climb the quality ladder in order to escape

competition. Bernard, Redding, and Schott (2011) show that a reduction of trade costs with a low-wage country leads to a change in the product mix offered by Northern firms towards more high-tech products. Bloom, Draka, and Van Reenen (2015) examine the effect of Chinese import competition on innovation and find a positive effect for firms affected by Chinese imports.¹⁷

To the extent that our treated and control firms can be differentially affected by import competition, a potential concern could be that a response to Chinese imports in U.S. product markets happening around our event, which arguably lowered trade costs, is driving our results on the process-product innovation mix. In contrast to the prediction of the import competition channel that our event would lead to a higher level of product innovations, Table 4 shows that the change in the process-product innovation mix is occurring through a lower level of process innovations.

To further rule out the import competition channel, we add in our baseline specification variable $Agreement_{(t>1999)}$ interacted with variable $IMPORT$, which measures import penetration from China at the 4-digit SIC level as in Bernard, Jensen, and Schott (2006). Columns 1-2 of Table 6 augment the specification in Column 3 of Table 3. In Column 1, $IMPORT$ is defined as the lagged level of import penetration, and, in Column 2, it is defined as the contemporaneous growth rate of import penetration. In both columns, the coefficient on the import penetration interaction is positive and not statistically significant, while the coefficient on the interaction term with the treated group remains negative, statistically significant, and is slightly larger in magnitude

A related argument in the international trade literature is that trade increases market size and induces firms to innovate by reducing the fixed cost of innovation (Krugman, 1980; Grossman and Helpman, 1991, 1992; Lileeva and Trefler, 2010). To examine the possibility that U.S. firms with a presence in China export more to China following the agreement, due to lower trade costs or demand shocks, and this may be affecting their technological choices, we investigate US exports to China. We add in our baseline specification vari-

¹⁷See also Amiti and Khandelwal, 2013; Hombert and Matray, 2015.

able $Agreement_{(t>1999)}$ interacted with variable $EXPORT$, defined as the growth rate of exports from U.S. to China at the 4-digit SIC level as in Schott (2008).

In Column 3 of Table 6, we show that this interaction is not statistically significant, while our effect of the agreement on treated firms remains. In Column 4, we add in our baseline specification the interaction of variable $Agreement_{(t>1999)}$ with import penetration growth as well as with export growth. Again, the effect of the agreement on treated firms remains, while the two interaction terms are neither economically nor statistically significant. Finally, the last two columns of Table 6 report results from analogous regressions for process and product innovations. In both cases, we again find similar results. It is interesting to note that the level effect of import penetration growth is positive and statistically significant for product innovations (Column 6) and not significant for process innovations (Column 5), which is consistent with the prediction from the trade literature that competition from low-wage countries spurs innovation of new products. We thus conclude that our findings do not seem to be due to U.S. firms responding to increasing Chinese imports or to higher U.S. exports to China.

IV.5 Other robustness

We perform additional robustness tests, which we include in Appendix C. We show our results are robust to matching treated and control firms by size and industry as of 1998 and to including in the sample only control firms with subsidiaries in low-wage Asian countries. We also show our results are robust to using alternate definitions for process and product innovations based on independent claims as well as on patents, and to defining our treated $China_i$ dummy from a second, independent source.

IV.6 Cross-sectional results

In this section, we exploit cross-sectional variation in our sample to highlight the underlying mechanism explaining our findings. First, we show that the negative effect on treated firms is more pronounced when US shareholders' equity share vis-à-vis the Chinese shareholders

is higher. Second, we find a weaker response to the agreement for U.S. firms which pay a higher wage bill in China. Third, we provide evidence that the negative effect on process innovations cannot be explained by weaker intellectual property rights in China.

IV.6.1 Equity shares

Our economic intuition is that the ability of U.S. firms to extract a higher portion of the profits vis-à-vis Chinese partners allows U.S. firms to take advantage of lower production costs in China. It is natural then to expect that the effect on their process-product innovation mix will be more pronounced in cases where US firms get a higher portion of the profits relative to their Chinese partners. In this section, we exploit cross-sectional variation in the relative equity shares of U.S. and Chinese partners and show results consistent with this prediction.

We use information from the 2001 Survey of Foreign Invested Enterprises (FIEs) conducted by the National Bureau of Statistics in China.¹⁸ The survey provides information on the equity shares of the U.S. and Chinese parties, which allows us to define the ratio of U.S. capital at registration over the Chinese capital at registration. The ratio ranges from 0.05 times (1st percentile) to 381 times (99th percentile), while the median ratio of U.S. to Chinese capital at registration is 3 times. Higher ratios mean that U.S. firms can extract a relatively higher share of the profits. We, thus, predict a more negative effect on the share and level of process innovations for higher ratios.

In Table 7, we augment our baseline specifications with interaction terms of our treated variable with the ratio of U.S. to Chinese capital at registration. Our coefficients of interest in this specification are the interaction terms. To the extent that any omitted variables are uncorrelated with our measure of equity ratios, the estimate can be interpreted as a triple-difference effect. Columns 1-2 present the effect on the share of process innovation. The triple difference effect is negative and significant at the 5% or 1% level. The effect

¹⁸In Table A2, we use the survey to get information on U.S. subsidiaries in China and show robustness of our baseline results.

is also economically significant. If the ratio of invested capital at registration increases from 1 to 100 times, the share of process innovation will be lower by 4% (Column 2). Similarly, the interaction term in Columns 3-4 is negative and statistically significant at the 5% level. If the ratio of invested capital at registration increases from 1 to 100 times, process innovations will be lower by 9% (Column 4).¹⁹

IV.6.2 Wage bill

Given our economic intuition goes through the labor channel, we predict a weaker treatment effect when the wage bill of U.S. subsidiaries in China is higher. To proxy for the wage bill of U.S. firms in China, we create a dummy which takes a value of 1 if the number of workers in the U.S. subsidiary is higher than the sample median and also the minimum wage growth rate in 1998 at the county where the subsidiary is located is higher than the sample median. We collect information on the number of workers in China from the 2001 Survey of Foreign Invested Enterprises (FIEs) conducted by the National Bureau of Statistics in China. The survey also provides information on the location of subsidiaries in China which allows matching to minimum wage data at the county level.²⁰

In Table 8, we augment our baseline specifications with interaction terms of our treated variable with a dummy which denotes subsidiaries with high wage bills. Our coefficient of interest in this specification is the interaction term. To the extent that any omitted variables are uncorrelated with our measure of wage bill, the estimate can be interpreted as a triple-difference effect. Columns 1-2 present the effect on the share of process innovation. The triple difference effect is positive and significant at the 10% level. Similarly, the interaction term in Columns 3-4 is positive and statistically significant at the 5% level for the level of process innovations.

¹⁹We get similar results if we use instead the ratio of accumulated investment amount by the U.S. investor over the accumulated investment amount by the Chinese investor.

²⁰The source of minimum wage data is Huang, Loungani, and Wang (2014). The data are originally collected by the Ministry of Human Resources and Social Security in China and official reports of local governments.

An intuitive rationale for this result is the following: if the effective wage is high because the actual labor wage is high and not because the share of the profit captured by the Chinese partners is high, then an increase of the share accruing to U.S. firms will not reduce the effective wage much, as the bulk of the effective wage is the actual labor wage paid to Chinese workers which does not depend on the split of the profit. These results are consistent with the notion that cheaper Chinese labor acts like labor saving technology substituting for process innovations.

IV.6.3 Intellectual property rights and secrecy

An alternative interpretation of our findings might be that firms with presence in China patent less process innovations following the agreement, as compared to firms with no such presence. According to this argument, intellectual property rights (IPR) are weakly enforced in China and thus, U.S. firms may prefer secrecy over patenting when they increase their exposure to China. This may be particularly relevant for process patents if these innovations are easier to steal or less enforceable in China.²¹ In this section, we discuss why a “secrecy” channel does not seem to be explaining our findings.

The triple difference results indicating a weaker treatment effect for high wage bill subsidiaries in China are consistent with our labor channel and not with a secrecy channel. However, we exploit cross-sectional variation in IPR protection within China and find no differences in firms’ innovation mix. Although IPR protection in China is considered overall weak, and is regulated at the national level, there is significant variation of IPR protection at the provincial level. Such variation of IPR enforcement across Chinese provinces has been shown to affect (Chinese) firms’ financing and investment choices (Ang, Cheng, and Wu, 2014), as well as firms’ R&D investments and innovations (Fang, Lerner, and Wu, 2015). We classify the subsidiaries in our sample in provinces with different degrees of IPR enforcement, following the measure developed by Ang, Cheng, and Wu (2014) and define a

²¹Levin et al. (1987) suggest that secrecy is more effective for protecting the returns to process innovation as process innovation is less easily observable.

variable (IPR) decreasing in IPR enforcement.²² If the secrecy channel is true, subsidiaries in provinces with lower IPR protection should be patenting less process innovations.

In Table 9, we augment our baseline specifications with interaction terms of our treated variable with the IPR variable, which is decreasing in IP protection enforcement. Our coefficients of interest in this specification are the interaction terms. Columns 1-2 present the effect on the share of process innovation and Columns 3-4 present the effect on the level of process innovation. The interaction coefficients are not statistically significant. If anything, the interaction coefficients have the opposite sign from what the secrecy channel would predict: lower IPR protection would predict a stronger differential treatment effect, and thus a negative interaction coefficient. These results alleviate concerns that differences in firms' propensity to patent process innovation due to risk of IP theft is explaining the results.

V An alternative experiment

In this section, we turn to an alternative experiment and we are able to replicate our baseline results. We exploit inter-temporal variation in ownership restrictions on foreign investment imposed by the Chinese government across industries, which change the share of the profits captured by the U.S. vis-à-vis the Chinese equity holders. We show that lower restrictions lead to lower share of process innovation. This result is again driven by a reduction in the number of process innovations, while product innovations do not change. This is an alternative experiment which confirms our baseline results.

V.1 Foreign investment catalogues

The 1999 U.S.-China bilateral agreement improved upon doing business in China, nevertheless restrictions on foreign investment still remain. In certain industries, for example,

²²Ang, Cheng, and Wu (2014) use the fraction of intellectual property infringement cases won by plaintiffs in individual provinces to measure the probability of winning by the plaintiffs in IP infringement cases.

foreign investors must invest only through a joint venture and have to reside within given ownership caps. Foreign ownership restrictions are formally published in a Catalogue issued by the Chinese government, the Catalogue of Industries Guiding Foreign Investment. This Catalogue is key for firms interested in investing in China and is issued jointly by the National Development and Reform Commission (“NDRC”) and the Ministry of Commerce (“MOFCOM”), China’s governing bodies on economic development and trade and investment policy, respectively.

Chinese government issued the Catalogue for the first time in 1995 in an effort to regulate foreign investment in China. Since then, the Catalogue has been revised five times: in 1997, 2002, 2004, 2007, and 2011. Despite the several revisions, the structure of the document remains the same across versions. The Catalogue indicates whether there are restrictions on foreign shareholdings by requiring specific types of foreign investment or by capping the percentage of foreign investment. Sectors not included in the Catalogue are “permitted”, as outlined in the Regulation on Guiding Foreign Investment Direction (State Council Order 346), and no ownership restrictions apply. Sectors included in the Catalogue are “encouraged”, “restricted”, or “prohibited” for foreign investors. “Restricted” sectors are sectors subject to ownership restrictions. “Encouraged” sectors can be either “permitted”, and thus no ownership restrictions apply, or “restricted” and are subject to ownership restrictions, but enjoy better regulatory approval procedures. Finally, there is a set of sectors which are “prohibited”, and thus no investment is allowed in those sectors.

We map the industry descriptions in the Catalogues into the industry descriptions of 4-digit NAICS industries.²³ For our purposes, we next group 4-digit NAICS industries into two categories: industries which are not subject to ownership restrictions (industries falling into this category may be permitted or encouraged) and those that are subject to such restrictions (industries falling in that category may be restricted, encouraged, or prohibited). We create a dummy variable which takes the value of 1 if an industry is not

²³Industry descriptions that do not match with those of the 4-digit NAICS sectoral classification are dropped from the analysis. Assuming these industries are permitted, and thus not included in the catalogues, does not qualitatively change the results.

subject to ownership restrictions for each year between the issue of the Catalogue and the year of issue of the next Catalogue, and 0 if such restrictions are in effect. Thus, we end up with time-series information on ownership restrictions for a total of 58 4-digit NAICS industries between 1995, the first year the Catalogues were issued, and 2012, the last year in our sample.

Figure 1 presents the percentage of industries in our sample that are not subject to restrictions at each point in time. Note that consistent with the fact that China has been opening up its markets to foreign investors, the percentage of industries not subject to restrictions is increasing over time. More interestingly, the biggest change is observed between the 1997 and the 2002 Catalogues, namely around China’s entry to WTO.

V.2 Empirical estimation

A change in the status of an industry from “restricted” to “permitted” has two implications for U.S. firms. A direct implication of lower ownership cap on U.S. shareholdings is an increase in the share of profits for U.S. firms as they are now allowed to own higher stakes. A second implication is an increase in the bargaining power of U.S. firms, which allows them to extract a higher share of the profits, vis-à-vis the Chinese partners. To fix ideas, you can think of sectors where the Chinese side had to hold (by law) the controlling interest (more than 50% of the firm). Similarly to our baseline experiment, lifting such restrictions allowed U.S. firms to sidestep, if necessary, the Chinese partners eliminating the potential for hold-up problems and incomplete contracts.²⁴ This implies a reduction in *effective* labor costs, which lowers the return on investing in process innovations.

To identify the relative changes in the share of process innovations, we employ a difference-in-differences approach, similar to our baseline specification. We estimate the change in the share of process innovation at firms with presence in China, relative to firms

²⁴This intuition is also consistent with the incomplete-contracting theories of integration in international environments where higher integration for foreign firms entitles them to residual rights of control, thus improving their ex-post bargaining position and alleviating underinvestment due to hold-up problems (Antràs 2003, 2013).

without such presence and whether the effect of having presence in China is different following the lower restrictions on foreign investors imposed by the Chinese government as compared to years when these restrictions were in effect. We estimate regressions of the following form:

$$y_{it} = \alpha_t + \lambda_i + \delta_1 \cdot \text{Industry}_{jt} \cdot \text{China}_{it} + \delta_2 \cdot \text{Industry}_{jt} + \delta_3 \cdot \text{China}_{it} + \beta \cdot X_{it-1} + \epsilon_{it} \quad (2)$$

where i , j , and t index firms, industries, and years; α_t and λ_i are year and firm fixed effects respectively; Industry_{jt} is a dummy variable that takes a value of 1 if an industry is not subject to ownership restrictions at a given year, and is 0 otherwise; China_{it} is an indicator variable which takes a value of 1 for firms in our treated group, namely those identified to have presence in China at a year t ; X_{it-1} are time-varying firm level control variables lagged by one year; and ϵ_{it} is the error term. The coefficient δ_1 measures the average within-firm changes in share of process innovation for firms operating in industries where restrictions on investment are lifted, after controlling for any concomitant systematic changes on innovation of firms which are still subject to restrictions. Our sample spans years 1995-2012 and includes intensely patenting firms. Given our experiment exploits variation across industries and over time, we use a time-varying treatment indicator China_{it} . In unreported regressions, we repeat our estimation defining treated firms as in our baseline analysis and find similar results. All variables are winsorized at the 1% level. Standard errors are robust and clustered at the 4-digit NAICS industry level.²⁵

Table 10 presents the results. Column 1 includes firm fixed effects and year fixed effects but does not include any other controls. We find that the share of process innovation in treated firms decreases by 5% following lower ownership caps, as compared to control firms, and is significant at the 1% level. In Column 2, we additionally control for firm sales and market to book ratio to control for size and changes in investment opportunities at the firm level. In Column 3, we additionally control for interacted industry and year fixed effects to better control for changes in investment opportunities at the industry level. The coefficient

²⁵In unreported regressions, we find our results are robust to clustering at the firm level.

remains statistically significant at the 1% or 5% level, and the magnitudes remain relatively unchanged. The fact that the additional controls have little impact on the results indicates that our results are not driven by differences in size or investment opportunities in the two groups.

In Columns 4-6 of Table 10, we present results on process and product innovations separately, repeating specifications in Table 4 of our baseline tests. Process innovations are lower by 25% (Column 6) and the effect is statistically significant at the 1% or 5% level. On the contrary, the effect on product innovations is not significant across specifications. Using an alternative setting, these results strengthen our conclusions that greater ability of U.S. firms to benefit from cheaper Chinese labor lead to lower process innovations.

VI Conclusion

China's entry into WTO has been an issue of long deliberations and still remains at the epicenter of contentious debates. The literature has focused on the impact of trade with China on the developed economies – China is one of the world's largest trading nations. However, China is also the largest recipient of foreign investment (\$128 billion in 2014 versus \$86 billion for the U.S.) by multinationals which want access to China's labor market. Our motivation is thus to examine how the large supply of cheap Chinese labor affects technological change through investing.

To answer this question, we use novel data on process and product innovations. We construct our measures using text-based analysis of patents filed in the U.S. We show that innovation mix shifted towards less process innovations for U.S. firms invested in China, following the 1999 U.S.-China bilateral agreement. The agreement increased the share of profits accruing to U.S. firms vis-à-vis the Chinese partners, lowering U.S. firms' *effective* labor costs. When Chinese labor is more attractive due to the agreement, process innovation (its substitute) is less attractive, decreasing the returns to investing in US-labor-saving process innovation. We are able to replicate the same results in a different setting, using inter-temporal variation of foreign ownership restrictions across industries between

1995 and 2012.

The 1999 bilateral agreement, as well as agreements signed with other countries, was certainly an important step towards improving doing business in China. A current, ongoing discussion is taking place on more reforms and bilateral investment treaties be signed with the United States and the European Union. Our results highlight that such reforms can be key determinants of technology choices of firms, allowing them to more efficiently organize their production. Such choices determine firms' innovation frontiers, and thereby identifying the forces behind those choices can further our understanding of productivity differences between firms.

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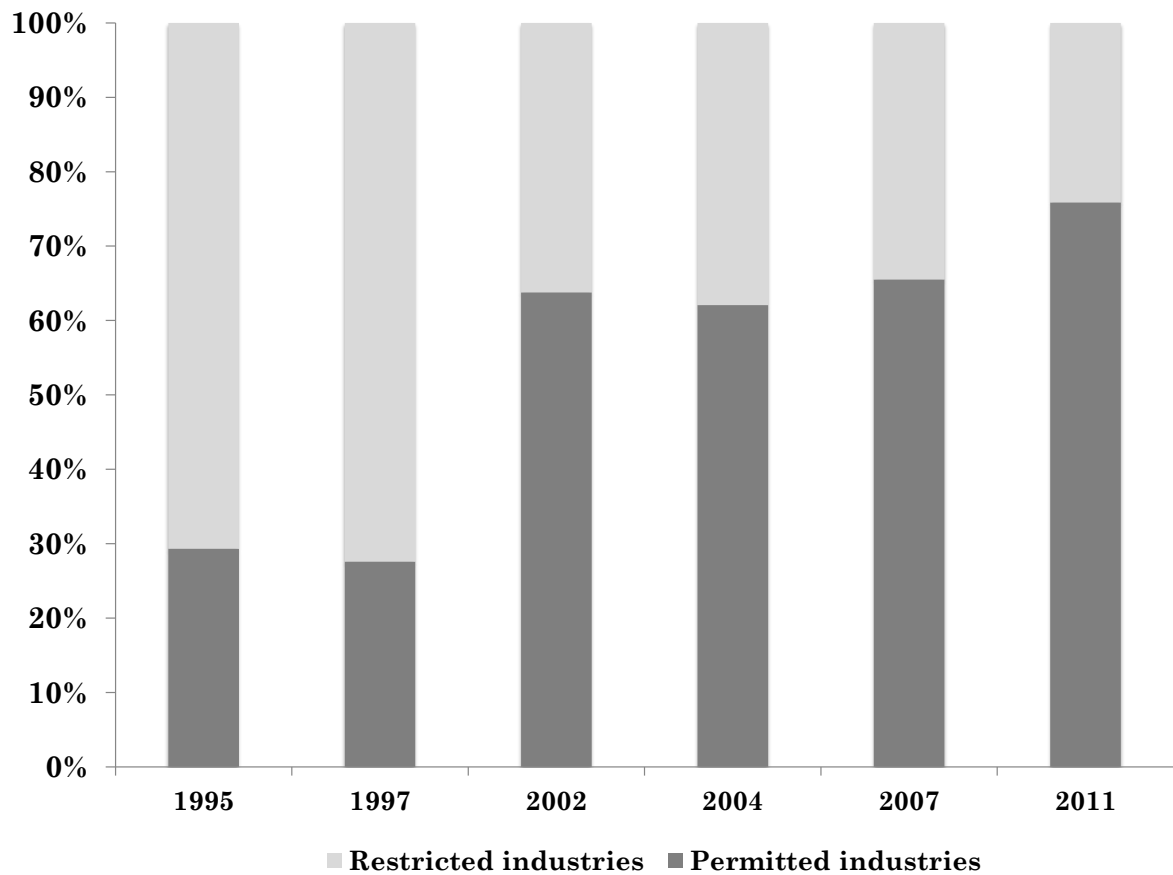


Figure 1. Breakdown of “Permitted” and “Restricted” industries for each Foreign Investment Catalogue

This figure shows the percentage of industries where investment is subject to ownership restrictions (light grey) and those where investment is permitted without ownership restrictions (dark grey). The information is provided by the Catalogue of Industries Guiding Foreign Investment issued jointly by the National Development and Reform Commission (“NDRC”) and the Ministry of Commerce (“MOFCOM”) of China. The Foreign Investment Catalogue was initially issued in 1995 and was revised five times since then: in 1997, 2002, 2004, 2007, 2011.

Table 1: Process and product innovations

This table reports summary statistics on patent claims for the set of patents assigned to Compustat firms in our baseline sample used in Table 3. There are 362,534 patents over the period 1995-2004. Patent claims define – in technical terms – the scope of protection conferred by a patent, and thus define what subject matter the patent protects. A process claim refers to innovations that reduce production costs, while product claims refer to new goods. An independent claim stands on its own, while a dependent claim, in contrast, only has meaning when combined with a claim it refers to.

	Mean	Standard Deviation	25th Percentile	50th Percentile	75th Percentile
Number of Claims	19.60	14.20	10	17	25
Number of Process Claims	7.36	9.73	0	5	11
Number of Product Claims	12.30	11.70	4	10	18
Number of Independent Claims	3.44	2.67	2	3	4
Number of Dependent Claims	16.20	13.00	8	14	21

Table 2: Summary statistics

This table reports summary statistics for key financial variables for the full sample, and for treated and control firms, as measured in 1998, the year prior to the US-China bilateral agreement. Treated firms are defined as intensely patenting firms which have a subsidiary in China as of 1998, and control firms are intensely patenting firms without such presence. Column 1 reports means, Column 2 reports standard deviations for the full sample. 25th, 50th and 75th percentiles are reported in Columns 3-5. Columns 6 and 7 present means and standard errors, respectively, for treated and control firms, as measured in 1998. Column 8 reports p-values from the t-test for the difference in means between treated and control firms.

	Mean	Standard Deviation	25th Percentile	50th Percentile	75th Percentile		Mean	Standard Errors	p-value of Difference
	All firm-years (N=2,399)						In Year 1998		
Share of Process Innovations	0.337	0.172	0.216	0.332	0.444	treated	0.328	(0.017)	0.52
						control	0.343	(0.017)	
Share of Process Innovations_Patent	0.330	0.212	0.175	0.301	0.458	treated	0.301	(0.020)	0.23
						control	0.336	(0.021)	
Sales (mil. \$)	10,402	23,190	864	2,409	9,293	treated	10,220	(1,830)	0.63
						control	8,860	(1,967)	
Assets (mil. \$)	13,607	34,926	1,014	2,836	10,529	treated	11,594	(2,671)	0.98
						control	11,464	(2,993)	
Employees (thous.)	36.79	62.44	4.02	11.65	40.29	treated	33.01	(5.78)	0.33
						control	40.94	(5.49)	
Cash (mil. \$)	1,258	2,869	80	275	955	treated	791	(88)	0.57
						control	857	(114)	
Long-term Debt (mil. \$)	2,483	7,656	33	417	1,606	treated	2,000	(548)	0.80
						control	2,236	(679)	
Ebitda (mil. \$)	1,841	4,207	131	396	1,536	treated	1,937	(300)	0.39
						control	1,501	(373)	
Capex (mil. \$)	783	2,253	47	148	519	treated	781	(183)	0.99
						control	785	(213)	
Market to Book	4.49	5.19	2.02	3.14	5.23	treated	5.91	(0.63)	0.31
						control	5.04	(0.58)	
Sales Growth (%)	9.57	23.97	-0.71	8.27	18.19	treated	6.31	(1.61)	0.23
						control	9.98	(2.34)	

Table 3: Price of labor and process-product innovation mix

This table reports results of regressions of the share of process innovations on treated firms following the 1999 US-China bilateral agreement as compared to a set of control firms. $China_i$ is a dummy which takes the value of 1 if a U.S. firm has a subsidiary in China in 1998, and is 0 otherwise. d_t is an indicator variable for year t . The sample period is 1995-2004. Market to Book is defined as the ratio of the market value of equity plus book value of debt over the book value of debt plus equity, log-transformed and lagged by one year. Sales is log-transformed and lagged by one year. All regressions include firm and year fixed effects. Columns 3-7 also include interacted 2-digit SIC times year fixed effects. Column 6 adds a full set of year dummies interacted with the dependent variable measured in 1998. Column 7 adds a full set of year dummies interacted with the natural logarithm of one plus the number of patents in 1998. All variables are winsorized at the 1% level. Standard errors are clustered at the firm-level. *** indicates $p < 0.01$, ** indicates $p < 0.05$, and * indicates $p < 0.1$.

	Share of Process Innovations						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$Agreement_{(t>1999)} \cdot China_i$	-0.0301 (0.0120)***	-0.0339 (0.0121)***	-0.0321 (0.0125)***	-0.0302 (0.0133)**		-0.0298 (0.0130)**	-0.0305 (0.0141)**
$d_{1997} \cdot China_i$					-0.0091 (0.0147)		
$d_{1998} \cdot China_i$					-0.0250 (0.0186)		
$d_{1999} \cdot China_i$				0.0072 (0.017)	-0.0045 (0.020)	0.0076 (0.016)	0.0058 (0.019)
$d_{2000} \cdot China_i$					-0.0360 (0.0177)**		
$d_{2001} \cdot China_i$					-0.0421 (0.0196)**		
$d_{2002} \cdot China_i$					-0.0407 (0.0202)**		
$d_{2003} \cdot China_i$					-0.0423 (0.0210)**		
$d_{2004} \cdot China_i$					-0.0489 (0.0218)**		
Sales		-0.0152 (0.0108)	-0.0176 (0.0110)	-0.0176 (0.0110)	-0.0175 (0.0110)	-0.0127 (0.0105)	-0.0180 (0.0109)*
Market to Book		0.0043 (0.0060)	-0.0002 (0.0060)	-0.0002 (0.0060)	0.0003 (0.0061)	-0.00003 (0.0061)	-0.0003 (0.0061)
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes					
Industry \times Year FE			Yes	Yes	Yes	Yes	Yes
Year FE \times $Process_{1998}$						Yes	
Year FE \times $Patents_{1998}$							Yes
R^2	0.72	0.76	0.80	0.80	0.80	0.81	0.80
Obs.	2,399	2,051	2,051	2,051	2,051	2,051	2,051

Table 4: Price of labor and process and product innovations

This table reports results of regressions of the level of process (Columns 1-4) and product innovations (Columns 5-8) on treated firms following the 1999 US-China bilateral agreement as compared to a set of control firms. Process and product innovations are log-transformed. The sample period is 1995-2004. Market to Book and Sales are defined as in Table 3. Patents is one plus the total number of patents at a given firm-year and is log-transformed. All regressions include firm and year fixed effects. Columns 4 and 8 also include interacted 2-digit SIC times year fixed effects. All variables are winsorized at the 1% level. Standard errors are clustered at the firm-level. *** indicates $p < 0.01$, ** indicates $p < 0.05$, and * indicates $p < 0.1$.

	Process Innovations				Product Innovations			
	(1)	(2)	(3)	(5)	(6)	(7)	(8)	(9)
$Agreement_{(t>1999)} \cdot China_i$	-0.323 (0.143)**	-0.182 (0.0566)***	-0.185 (0.0571)***	-0.187 (0.0584)***	-0.151 (0.131)	-0.0165 (0.0368)	-0.0061 (0.0364)	-0.0221 (0.0388)
Sales			-0.0483 (0.0399)	-0.0454 (0.0415)			0.0387 (0.0356)	0.0386 (0.0356)
Market to Book			0.0589 (0.0263)**	0.0403 (0.0282)			0.0399 (0.0188)**	0.0397 (0.0187)**
Patents		1.157 (0.0272)***	1.130 (0.0320)***	1.118 (0.0314)***		1.106 (0.0207)***	1.095 (0.0226)***	1.103 (0.0249)***
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	
Industry \times Year FE				Yes				Yes
R^2	0.77	0.93	0.94	0.95	0.75	0.96	0.96	0.97
Obs.	2,399	2,399	2,051	2,051	2,399	2,399	2,051	2,051

Table 5: Potential confounds: Economic shocks

This table reports results of regressions of the share of process innovations (Columns 1-2), level of process (Columns 3-4) and level of product innovations (Columns 5-6) on treated firms following the 1999 US-China bilateral agreement as compared to a set of control firms. $Asia, NON - China_i$ is an indicator which takes a value of 1 if a US firm has a subsidiary in Asia, but not China, and 0 otherwise. The sample period is 1995-2004. Firm-level controls include Market to Book ratio and firm sales in all columns and number of patents in Columns 3-6. Market to Book and Sales are defined as in Table 3. Patents is defined as in Table 4. All regressions include firm and year fixed effects. Columns 2, 4 and 6 also include interacted 2-digit SIC times year fixed effects. All variables are winsorized at the 1% level. Standard errors are clustered at the firm-level. *** indicates $p < 0.01$, ** indicates $p < 0.05$, and * indicates $p < 0.1$.

	Share of Process Innovations		Process Innovations		Product Innovations	
	(1)	(2)	(3)	(4)	(5)	(6)
$Agreement_{(t>1999)} \cdot China_i$	-0.0308 (0.0183)*	-0.0344 (0.0189)*	-0.198 (0.0715)***	-0.209 (0.0756)***	-0.0207 (0.0511)	-0.0227 (0.0563)
$Agreement_{(t>1999)} \cdot Asia, NON - China_i$	0.0044 (0.0192)	-0.0033 (0.0189)	-0.0193 (0.0786)	-0.0315 (0.0854)	-0.0210 (0.0537)	-0.0008 (0.0618)
Firm-level Controls	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes		Yes		Yes	
Industry \times Year FE		Yes		Yes		Yes
R^2	0.76	0.80	0.94	0.95	0.96	0.97
Obs.	2,051	2,051	2,051	2,051	2,051	2,051

Table 6: International trade and process-product innovation mix

This table reports results of regressions of the share of process innovations (Columns 1-4), process (Column 5) and product (Column 6) innovations on treated firms following the 1999 US-China bilateral agreement as compared to a set of control firms. *IMPORT* is measured as the level of lagged Chinese import penetration in the U.S. in Column 1, and as the growth rate of Chinese import penetration in Columns 2 and 4-6. *EXPORT* is measured as the export growth rate of the U.S. to China. *IMPORT* is measured as in Bernard, Jensen, and Schott (2006) and is available for manufacturing 4-digit SIC industries. *EXPORT* is computed based on U.S. exports to China available for 4-digit SIC manufacturing industries from Schott (2008). The sample period is 1995-2004. Firm-level controls include Market to Book ratio and firm sales in all columns and number of patents in Columns 5-6. Market to Book and Sales are defined as in Table 3. Patents is defined as in Table 4. All regressions include firm and interacted 2-digit SIC times year fixed effects. All variables are winsorized at the 1% level. Standard errors are clustered at the firm-level. *** indicates $p < 0.01$, ** indicates $p < 0.05$, and * indicates $p < 0.1$.

	Share of Process Innovations				Process Innovations	Product Innovations
	(1)	(2)	(3)	(4)	(5)	(6)
<i>Agreement</i> _($t > 1999$) · <i>China</i> _{<i>i</i>}	-0.0366 (0.0161)**	-0.0369 (0.0163)**	-0.0363 (0.0164)**	-0.0364 (0.0163)**	-0.235 (0.0813)***	-0.0307 (0.0449)
<i>Agreement</i> _($t > 1999$) · <i>IMPORT</i>	0.00669 (0.0497)	0.00573 (0.00841)		0.00547 (0.00847)	0.0186 (0.0475)	0.00678 (0.0224)
<i>Agreement</i> _($t > 1999$) · <i>EXPORT</i>			-0.0117 (0.0103)	-0.0099 (0.0105)	-0.0267 (0.0436)	0.0332 (0.0229)
<i>IMPORT</i>	-0.176 (0.182)	-0.0007 (0.0003)**		-0.0007 (0.0003)**	-0.0006 (0.0007)	0.0025 (0.0007)***
<i>EXPORT</i>			0.00216 (0.0036)	0.0014 (0.0039)	-0.00001 (0.0014)	-0.0082 (0.0113)
Firm-level Controls	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry × Year FE	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.75	0.75	0.75	0.75	0.94	0.97
Obs.	1,346	1,325	1,325	1,325	1,325	1,325

Table 7: Cross-sectional heterogeneity by the share of capital in the subsidiary

This table reports results of regressions of the share of process innovations (Columns 1-2) and level of process innovations (Columns 3-4) on treated firms following the 1999 US-China bilateral agreement as compared to a set of control firms. $China_i$ is defined based on the 2001 survey of foreign invested enterprises conducted by the National Bureau of Statistics in China, which we linked to Compustat. $EquityRatio_i$ is defined as the ratio of US capital at registration over Chinese capital at registration for the U.S. subsidiary in China. The sample period is 1995-2004. Firm-level controls include Market to Book ratio and firm sales in all columns and number of patents in Columns 3-4. Market to Book and Sales are defined as in Table 3. Patents is defined as in Table 4. All regressions include firm and year fixed effects. Columns 2, and 4 also include interacted 2-digit SIC times year fixed effects. All variables are winsorized at the 1% level. Standard errors are clustered at the firm-level. *** indicates $p < 0.01$, ** indicates $p < 0.05$, and * indicates $p < 0.1$.

	Share of Process Innovations		Process Innovations	
	(1)	(2)	(3)	(4)
$Agreement_{(t>1999)} \cdot China_i$	-0.0155 (0.0134)	-0.0033 (0.0144)	-0.0779 (0.0601)	-0.0461 (0.0646)
$Agreement_{(t>1999)} \cdot China_i \cdot EquityRatio_i$	-0.00041 (0.00016)**	-0.00039 (0.00013)***	-0.00123 (0.00049)**	-0.00094 (0.00048)**
Firm-level Controls	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes		Yes	
Industry \times Year FE		Yes		Yes
R^2	0.78	0.82	0.94	0.95
Obs.	1,766	1,766	1,766	1,766

Table 8: Cross-sectional heterogeneity by the wage bill of the subsidiary

This table reports results of regressions of the share of process innovations (Columns 1-2) and level of process innovations (Columns 3-4) on treated firms following the 1999 US-China bilateral agreement as compared to a set of control firms. $China_i$ is defined based on the 2001 survey of foreign invested enterprises conducted by the National Bureau of Statistics in China, which we linked to Compustat. $WageBill_i$ is an indicator which is 1 if the number of workers at the US subsidiary in China is higher than the sample median and, at the same time, the growth rate of the subsidiary's county minimum wage in 1998 is higher than the sample median, and is 0 otherwise. The sample period is 1995-2004. Firm-level controls include Market to Book ratio and firm sales in all columns and number of patents in Columns 3-4. Market to Book and Sales are defined as in Table 3. Patents is defined as in Table 4. All regressions include firm and year fixed effects. Columns 2, and 4 also include interacted 2-digit SIC times year fixed effects. All variables are winsorized at the 1% level. Standard errors are clustered at the firm-level. *** indicates $p < 0.01$, ** indicates $p < 0.05$, and * indicates $p < 0.1$.

	Share of Process Innovations		Process Innovations	
	(1)	(2)	(3)	(4)
$Agreement_{(t>1999)} \cdot China_i$	-0.0471 (0.0149)***	-0.0353 (0.0168)**	-0.255 (0.0734)***	-0.217 (0.0820)***
$Agreement_{(t>1999)} \cdot China_i \cdot WageBill_i$	0.0348 (0.0213)*	0.0393 (0.0233)*	0.218 (0.106)**	0.208 (0.0944)**
Firm-level Controls	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes		Yes	
Industry \times Year FE		Yes		Yes
R^2	0.77	0.81	0.93	0.94
Obs.	1,529	1,529	1,529	1,529

Table 9: Cross-sectional heterogeneity by IP protection of the subsidiary

This table reports results of regressions of the share of process innovations (Columns 1-2) and level of process innovations (Columns 3-4) on treated firms following the 1999 US-China bilateral agreement as compared to a set of control firms. $China_i$ is defined based on the 2001 survey of foreign invested enterprises conducted by the National Bureau of Statistics in China, which we linked to Compustat. IPR is decreasing at the degree of intellectual property rights enforceability by province in China. It is based on the measure developed by Ang, Cheung, and Wu (2014), and in particular, on the average percentage of IP infringement cases won by plaintiffs during the 2001-2005 period. IPR takes values from 0-4, with higher values corresponding to provinces in China with lower percentages of IP infringement cases won by plaintiffs at the local courts. The sample period is 1995-2004. Firm-level controls include Market to Book ratio and firm sales in all columns and number of patents in Columns 3-4. Market to Book and Sales are defined as in Table 3. Patents is defined as in Table 4. All regressions include firm and year fixed effects. Columns 2, and 4 also include interacted 2-digit SIC times year fixed effects. All variables are winsorized at the 1% level. Standard errors are clustered at the firm-level. *** indicates $p < 0.01$, ** indicates $p < 0.05$, and * indicates $p < 0.1$.

	Share of Process Innovations		Process Innovations	
	(1)	(2)	(3)	(4)
$Agreement_{(t>1999)} \cdot China_i$	-0.0377 (0.0357)	-0.0118 (0.0402)	-0.313 (0.164)*	-0.283 (0.170)*
$Agreement_{(t>1999)} \cdot China_i \cdot IPR$	0.0081 (0.0188)	0.0008 (0.0212)	0.103 (0.0857)	0.108 (0.0920)
Firm-level Controls	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes		Yes	
Industry×Year FE		Yes		Yes
R^2	0.76	0.80	0.94	0.95
Obs.	1,956	1,956	1,956	1,956

Table 10: Foreign investment catalogues and process-product innovation mix

This table reports results of regressions of the share of process innovations (Columns 1-3), level of process (Columns 4-6), and level of product (Columns 7-9) innovations on firms operating in industries where ownership restrictions are lifted as compared to a set of control firms. $Industry_{jt}$ takes a value of 1 if an industry is not subject to ownership restrictions at a given year, and 0 otherwise, and it is defined at the 4-digit NAICS level. $China_{it}$ takes a value of 1 if a U.S. firm has a subsidiary in China in year t , and is 0 otherwise. The sample period is 1995-2012. Firm-level controls include Market to Book and firm sales in Columns 2-3, 5-6 and 8-9. Firm-level controls additionally control for patents in Columns 4-9. Market to Book and Sales are defined as in Table 3. Patents is defined as in Table 4. All regressions include firm and year fixed effects. Columns 3, 6 and 9 also include interacted 2-digit SIC times year fixed effects. All variables are winsorized at the 1% level. Standard errors are clustered at the 4-digit NAICS-level. *** indicates $p < 0.01$, ** indicates $p < 0.05$, and * indicates $p < 0.1$.

	Share of Process Innovations			Process Innovations			Product Innovations		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
$Industry_{jt} \cdot China_{it}$	-0.0504 (0.0184)***	-0.0611 (0.0188)***	-0.0516 (0.0221)**	-0.234 (0.0906)***	-0.257 (0.0983)***	-0.252 (0.113)**	0.0332 (0.0570)	0.0730 (0.0639)	0.0436 (0.0599)
$China_{it}$	0.0468 (0.0129)***	0.0558 (0.0140)***	0.0483 (0.0139)***	0.297 (0.0780)***	0.306 (0.0948)***	0.250 (0.101)**	0.0093 (0.0454)	-0.0464 (0.0576)	-0.0667 (0.0609)
$Industry_{jt}$	0.0321 (0.0144)**	0.0352 (0.0133)**	0.0062 (0.0173)	0.0575 (0.0749)	0.106 (0.0702)	0.0725 (0.119)	-0.103 (0.0621)	-0.0793 (0.0648)	0.0167 (0.0596)
Firm-level controls		Yes	Yes		Yes	Yes		Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes		Yes	Yes		Yes	Yes	
Industry \times Year FE			Yes			Yes			Yes
R^2	0.58	0.61	0.64	0.88	0.89	0.90	0.89	0.90	0.91
Obs.	3,855	3,400	3,400	3,855	3,400	3,400	3,855	3,400	3,400

Appendix A: Process and product innovations

Procedure to Distinguish Claim Types

Patent grant publication documents are structured using Extensible Markup Language (XML), a markup language that defines a set of rules for encoding documents in a format that is both human-readable and machine-readable. Within a patent grant publication document, claims are numbered sequentially, with the first claim typically being the broadest and the most important one. Claims are of two basic types: product or process. Claims are written in a very legalistic and stilted way, which allows us to apply text analysis techniques to clearly determine the claim type. Claims that refer to process innovations begin with “A method for” or “A process for” (or minor variations of these two strings) followed by a verb (typically in gerund form), which directs to actions that are to take place as part of the process. We denote claims with such beginnings as process claims, while we denote the residual as product claims. Claims are also either independent or dependent. An independent claim stands on its own, while a dependent claim has meaning only when combined with a claim it refers to. We machine-read the text of each claim in order to identify references the claim makes to other claims of the same patent. We denote claims that contain such references as dependent claims, while we denote the residual as independent claims.

For example, USPTO patent grant document U.S. 6533885 B2 titled “Apparatus and method for manufacturing a shoe upper” applied for on August 3, 2001 by Reebok International Ltd. has 14 claims. Claims 1 to 9 protect apparatus, i.e., a tool used in manufacturing of an upper for a shoe, and claims 10 to 14 protect a method for manufacture of a shoe upper. The wording of claim 1 begins: “1. A tool for manufacturing an upper for a shoe comprising...” The wording of claim 2 begins: “2. A tool according to claim 1, wherein said tool is...” The wording of claim 10 begins: “10. A method for manufacture of a shoe upper comprising...” The wording of claim 11 begins: “11. A method according to claim 10, further comprising the step of...” We code claims 1 to 9 to be product claims, while we code claims 10 to 14 to be process claims. We code claims 1 and 10 to be independent, and

claims 2 to 9 and 11 to 14 to be dependent.

Summary Statistics

Table A1 reports summary statistics on claim types per patent. Panel A is based on the universe of 4,233,476 utility patents applied for at USPTO by firms with application dates between January 1976 and December 2012. On average, a patent has 15.2 claims, of which 4.6 are process, 10.7 are product, 2.7 are independent, and 12.5 are dependent. In this sample, process claims are 30% of total claims, and product claims are 70% of total claims. When we look at the patent decomposition, there are 15.4% process patents, 56% product patents, 11.3% process-apparatus patents, and 17.4% product-method patents. Panel B is based on 1,855,328 utility patents applied for at USPTO by firms matched to Compustat with application dates between January 1976 and December 2012. The innovation mix of Compustat firms is very similar to that of the patent universe. Specifically, on average, a patent has 16.0 claims, of which 5.3 are process, 10.7 are product, 2.9 are independent, and 13.1 are dependent. In this sample, process claims are 33% of total claims, and product claims are 67% of total claims. When we look at the patent decomposition, there are 16.7% process patents, 49% product patents, 14.5% process-apparatus patents, and 20.1% product-method patents.

External Validity: Survey Evidence & Some Illustrative Correlations

Since we are the first to decompose innovations into new products and processes using patent data for a broad sample of firms, we provide several validity checks on main measures used in our analyses. First, we compare the process-product innovation mix computed using our data with that reported by other sources. The ‘Business Research and Development and Innovation Survey’ in the U.S., conducted by the National Science Foundation (NSF), reports the number of R&D performing firms that introduced new products or processes every year since 2006. On average, 42% of firms performing R&D over the 2006-2011 period, and 44% of firms with R&D activity over \$100 million, report that they perform process innovation. Comparably, using our data, we find that 46% of Compustat firms patented process innovations over the same period. We also find that, over the same period

on average, 39% of patented innovations are process innovations, albeit there is no question in the NSF survey that would allow us to make a direct comparison.²⁶ Analogous statistics to those available in the NSF survey are also provided by the ‘European Firms in Global Economy: internal policies for external competitiveness’ (EFIGE) survey performed in 2010 in 8 European countries. Table A2 in Appendix A shows that the percentage of firms active in process innovation ranges from 40 to 51 in these countries. Overall, both surveys confirm our finding that about 45% of R&D-active firms engage in process innovation.

Next, we qualitatively validate our measures relying on the findings of the job polarization literature. There are two prominent explanations in this literature for the displacement of the middle-skilled jobs that we observe in the aggregate data. The first explanation is that technological progress allows firms to replace expensive labor that performs routine tasks with technology (Autor, Levy, and Murnane 2003; Acemoglu and Autor, 2011). To the extent that process innovations are aimed at reducing production cost (Scherer (1982, 1984); Link 1982; Cohen and Klepper, 1996; Eswaran and Gallini, 1996), we predict that process innovations displace routine labor tasks that can be more easily performed by technology. Due to this displacement, we should observe a negative correlation between process innovations and the subsequent change in the labor routine tasks intensity. The second explanation is that the globalization of labor markets allows firms to offshore part of their production to low-wage countries (Blinder 2009; Blinder and Krueger, 2013). This implies that process innovations should be less beneficial if labor tasks are easily offshorable. We show evidence consistent with both predictions in Table A3 and in Table A4 in Appendix A.

We classify labor routine tasks intensity at the industry-year level. We use the Occupational Employment Statistics (OES), provided by the Bureau of Labor Statistics, to obtain information on total employment by occupation for each 4-digit NAICS industry over the 2002-2012 period. Using the classification of tasks’ routine intensity in Autor, Levy, and Murnane (2003) and Standard Occupational Classification (SOC) codes, we construct the

²⁶Estimates from earlier studies of the average process share in the manufacturing sector in the 1980s ranges between 25% to 30%. See Cohen and Klepper (1996) for a more detailed discussion.

average routine intensity of occupations in a given 4-digit NAICS industry-year, weighted by total employment for each occupation in a given industry-year.²⁷ Consistent with our intuition, Table A3 in the Appendix A shows that higher shares and levels of process innovations are negatively associated with the change in an industry’s labor routine tasks intensity over the subsequent 5 years.

We are also able to characterize the offshorability of labor tasks at the industry level. We match the classification of occupations by offshorability provided by Blinder (2009), available for about 290 SOC codes, to 4-digit NAICS industries. To do this, we need to use SOC crosswalks and information on occupations by industry available from the OES data. In Table A4, we show that industries with inherently a higher degree of offshorability are associated with lower shares and levels of process innovations.

Finally, we rely on patent data to validate our measure. We search for keywords indicating labor-saving technologies in patent descriptions over the period 1995-2012. Such keywords include, for example: *reduce labor*, *save labor*, *decrease labor intensity*, *reduce wage costs*, *substitute manual workers*, *replace labor force*, *reduce manpower*. We next aggregate the number of patents including references to reducing labor costs at the firm-year level for Compustat firms and construct the variable *Share of Patents with Labor References_{it}*. In Table A5, we show a positive and significant correlation at the firm-year level between the share of patents with specific references to labor cost reductions and the share or level of process innovations. The correlation instead with product innovations is zero. Note, unlike our process-product innovation measure, patent descriptions do not follow specific set of rules and are, therefore, less reliable. Nevertheless, these correlations are informative and consistent with what we would expect.

²⁷The BLS and the National Crosswalk Service Center in the U.S. provide crosswalks that allow us to match the SOC codes in the OES data with the Autor, Levy, and Murnane (2003) job title classifications.

Table A1: Process and product innovations

This table reports summary statistics on patent claims for the universe of utility patents (Panel A) and the utility patents matched to Compustat firms (Panel B) which applied for at USPTO with application dates from January 1976 till December 2012. Panel A refers to 4,233,476 patents. Panel B refers to 1,855,328 patents. Patent claims define – in technical terms – the scope of protection conferred by a patent, and thus define what subject matter the patent protects. A process claim refers to innovations that reduce production costs, while product claims refer to new goods. An independent claim stands on its own, while a dependent claim, in contrast, only has meaning when combined with a claim it refers to.

Panel A: Universe of Patents					
	Mean	Standard Deviation	25th percentile	50th percentile	75th percentile
Number of Claims	15.20	12.40	7	13	20
Number of Process Claims	4.56	8.16	0	0	7
Number of Product Claims	10.70	10.50	3	9	15
Number of Independent Claims	2.70	2.29	1	2	3
Number of Dependent Claims	12.50	11.40	5	10	17
Panel B: Compustat Firms' Patents					
	Mean	Standard Deviation	25th percentile	50th percentile	75th percentile
Number of Claims	16.00	12.60	8	14	20
Number of Process Claims	5.33	8.33	0	1	8
Number of Product Claims	10.70	10.60	3	9	15
Number of Independent Claims	2.93	2.43	1	2	4
Number of Dependent Claims	13.10	11.50	6	11	17

Table A2: Process-product innovation mix: Survey comparisons

This table reports the percentage of R&D performing firms which reported to have introduced process innovations at the National Science Foundation (NSF) survey for the U.S., and the EFIGE (European Firms in a Global Economy: internal policies for external competitiveness) survey for Europe. This number is compared to the universe of Compustat firms with process patents during the same time period. The reported number for the NSF is the average percentage of R&D performing firms doing process innovations over the period 2006-2011 (in particular, it is based on the answers to three NSF surveys: 2006-08, 2008-10, 2010-11). The reported number for Compustat is the average number of firms which have patented process innovations over the 2006-2011 period. The EFIGE survey took place in early 2010 and covers 8 European countries.

	Source	% of of R&D firms performing process innovation
U.S.	NSF	42
U.S.	Compustat	46
Austria	EFIGE	48
France	EFIGE	44
Germany	EFIGE	43
Hungary	EFIGE	40
Italy	EFIGE	45
Spain	EFIGE	51
UK	EFIGE	43

Table A3: Process-product innovation mix and industry routine job intensity

This table shows the results of the regression of the share of process innovations (Column 1) and level of process innovations (Column 2) in a 4-digit NAICS industry j at time t on a rolling window of 5-year changes of the industry's j routine intensity between t and $t+5$. Innovation measures for each year and industry are computed from the universe of Compustat firms with patent data. To measure the routine intensity of a given occupation, we follow Autor, Levy, and Murnane (2003) and compute the ratio of routine tasks over the sum of all tasks. Routine tasks include the sum of routine cognitive and routine manual tasks and the denominator includes the sum of all routine and non-routine tasks, as defined by ALM. All variables are available in ALM and we match them to occupations at a given 4-digit NAICS industry and year using the OES data and Crosswalks provided by BLS and the Crosswalk Service Center. For a given industry-year, we take the average of routine intensity of the industry's occupations, weighted by employment of occupations at this industry and year. The sample period is 2002-2012. Standard errors are clustered at the 4-digit NAICS industry level. *** indicates $p < 0.01$, ** indicates $p < 0.05$, and * indicates $p < 0.1$.

	$\Delta(\text{Industry Routine Tasks Share})_{t,t+5}$	
	(1)	(2)
<i>Share of Process Innovations</i> $_{jt}$	-0.907 (0.533)*	
<i>Process Innovations</i> $_{jt}$		-0.132 (0.0805)*
<i>Product Innovations</i> $_{jt}$		0.153 (0.119)
Year FE	Yes	Yes
R^2	0.06	0.06
Obs.	685	685

Table A4: Offshorability and process-product innovation mix

This table reports the results from cross-sectional regressions of the offshorability of occupations at a given 4-digit NAICS industry on the industry share of process innovations (Column 1), and the industry level of process innovations (Column 2). The offshorability of occupations is based on the index provided by Blinder (2009) classifying the offshorability of 291 SOC occupations in the 2004 U.S. workforce. Using crosswalks provided by BLS and the Crosswalk Service Center, we match the index to occupations provided by OES for each 4-digit NAICS-year level. Since the offshorability index is time-invariant, we collapse the innovation measures at the industry level (over the period 2002-2012). Standard errors are robust. *** indicates $p < 0.01$, ** indicates $p < 0.05$, and * indicates $p < 0.1$.

	Share of Process Innovations	Process Innovations
	(1)	(2)
<i>Offshorability</i>	-0.0161 (0.00605)***	-0.0450 (0.0263)*
<i>Patents_j</i>		1.370 (0.0340)***
R^2	0.05	0.88
Obs.	176	176

Table A5: “Labor Patents”

This table reports the results from panel regressions between the share of patents including references to labor costs and our measures of process-product innovation mix. The sample includes Compustat firms for the period 1995-2012. Columns 1-2 include all firm-years, while Columns 3-4 include firm-years for which total number of claims is greater than the sample median. Our dependent variable is based on the count of patents including keywords indicating reduction of labor costs. Such keywords include: *reduce labor, save labor, decrease labor intensity, reduce wage costs, substitute manual workers, replace labor force, reduce manpower*. All regressions include firm and year fixed effects. Standard errors are robust and clustered at the firm level. *** indicates $p < 0.01$, ** indicates $p < 0.05$, and * indicates $p < 0.1$.

	Share of Patents with Labor References			
	(1)	(2)	(3)	(4)
	firm patent claims > sample median			
<i>Share of Process Innovations_{jt}</i>	0.00245 (0.0021)		0.00536 (0.00306)*	
<i>Process Innovations_{jt}</i>		0.0009 (0.0004)**		0.0129 (0.0005)**
<i>Product Innovations_{jt}</i>		-0.0001 (0.0004)		-0.0007 (0.0006)
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
R^2	0.41	0.41	0.45	0.45
Obs.	46,078	46,078	26,068	26,068

Appendix B: The 1999 U.S.-China bilateral agreement

Figure B1 presents the timeline of the events surrounding the 1999 U.S.-China bilateral agreement (see Devereaux and Lawrence, 2004). Given the timeline, it is important to emphasize that the information that China was willing to make significant concessions in the negotiations was revealed with the visit of Premier Zhu in the U.S. in April 1999, and was confirmed with the agreement signed a few months later. However, note that some uncertainty still remained as the benefits of the agreement would be fully capitalized if China entered WTO, which required U.S. to grant China permanent normal trade relations (PNTR). The U.S. had to commit to nondiscriminatory treatment by making China's most favored nation (MFN) status permanent, namely give up annual reviews of China's trade status.²⁸

Controversy on whether PNTR would be approved by Congress triggered unprecedented lobbying by business interests, which manifests the important investment benefits of the agreement for U.S. firms. Despite the fact that the agreement included provisions that labor unions had supported, such as the antidumping methodology that would remain in force for 15 years after China's accession to WTO and safeguards for certain U.S. domestic industries such as textiles and apparel, labor unions remained strong opponents of the bill.²⁹ In addition to unions, human rights organizations, consumer groups, and a set of more backward industries (e.g. textile) which feared Chinese imports, were adamantly opposing the bill. The bill seemed to be unpopular among the American public, while a sizable number of the House was publicly against the bill.

On the contrary, big U.S. firms were pushing for the legislation to pass in an organized

²⁸Since 1979, U.S. and China had most favored nation (MFN) trading status, which was subject to an annual review by the U.S.

²⁹Two days after the November bilateral agreement, AFL-CIO and 12 industrial unions sent a letter to the Congress asking them to vote against PNTR (Devereaux and Lawrence, 2004).

effort of intense lobbying and advertising campaign.³⁰ Although the public debate focused on exports, U.S. firms were primarily interested in the investment benefits of the agreement. According to a Morgan Stanley Economist, “*debate focused on exports, but for many companies going local is the goal.*” The director of global economic policy at the New America Foundation notes: “*U.S. exports will increase over time. But not at the rate of investment, and the corporate community has been quiet about that.*”³¹ Due to the heated debate, the U.S. business interests were cautious not to provide labor unions with arguments that jobs would be lost because of U.S. companies moving their production to China.

The U.S. House of Representatives voted to grant China PNTR on May 24, 2000 – by a margin of 237 to 197. The Senate approved the bill in September 2000, and the law was signed by the President in October 2000.

³⁰The United States Chamber of Commerce and the Business Roundtable alone spent \$10 million against \$2 million spent by labor (Devereaux and Lawrence, 2004).

³¹The Wall Street Journal, May 25, 2000, A1. See Devereaux and Lawrence (2004).

Figure B1

The 1999 US-China Bilateral Agreement and Permanent Normal Trade Relations (PNTR)

- 1947:** China is one of the 23 original GATT contracting parties.
- 1949:** The Chinese Communist Party defeats the Nationalist Party.
- 1950:** Nationalist China pulls out of the GATT.
- 1951:** President Truman suspends China's most favored nation (MFN) trading status.
- 1971:** The United Nations recognizes the Communist government of the People's Republic of China as the sole legal Chinese representative in the United Nations.
- 1978:** Deng Xiaoping launches economic reform in China.
- 1980:** The United States conditionally restores MFN trading status to China to be reviewed annually under the Jackson-Vanik amendment of the Trade Act of 1974.
- 1982:** The GATT grants China's request for nonvoting observer status.
- 1986:** China requests the restoration of its status as a full contracting party to the GATT.
- 1989:** Unarmed protesters are killed at Tiananmen Square.
- 1993:** President Clinton issues an executive order to make China's MFN trade status conditional on improvement in six areas, including human rights.
- 1994:** Clinton renews China's MFN status.
- 1994:** Beijing accelerates drive to join the GATT, hoping to become a founding member of the WTO.
- 1995:** The WTO replaces the GATT.
- 1997:** President Jiang Zemin and President Clinton hold a summit in Washington, DC.
- 1999:** Chinese premier Zhu Rongji tells US Federal Board Chairman Alan Greenspan that he is ready to make a deal.
- Mar. 1999:** USTR Charlene Barshefsky visits China.
- Apr. 1999:** Premier Zhu Rongji comes to United States. In a controversial move, President Clinton chooses not to close the US-China bilateral.
- May 7, 1999:** The United States mistakenly bombs the Chinese Embassy in Belgrade.
- Sept. 11, 1999:** President Clinton and President Jiang Zemin discuss restarting trade talks during New Zealand Economic Summit

Nov. 8, 1999: Clinton sends USTR Charlene Barshefsky and his economic adviser Gene Sperling to China.

Nov. 15, 1999: The US-China bilateral agreement is reached.

May 24, 2000: The US House of Representatives votes to grant China permanent normal trade relations (PNTR) status upon its accession to the WTO.

Sept. 19, 2000: The US Senate passes PNTR.

Oct. 10, 2000: President Bill Clinton signs PNTR.

Dec. 11, 2001: China becomes the 143rd member of the WTO.

Source: Devereaux and Lawrence (2004, Exhibit 1).

Appendix C - Robustness

Different sample cutoffs for defining high-patenting firms

In our baseline analysis, we condition our sample on firms having filed for at least 150 patents over the 1995-2004 period. This is important as our main variable *Share of process innovations* $_{it}$ is defined if there is at least one patent for each firm-year and it provides a meaningful measure of the changes in firms' process-product innovation mix only for firms with a non-trivial number of patents. In Table C1, we repeat specifications in Columns 1-3 of Table 3 using different cutoffs to define high patenting firms. In Panel A, we present regressions including all firms in our initial sample. The coefficient on the interaction term is negative and economically significant, but not statistically significant (p-value is 0.18 in Column 1). In Panel B, we restrict the sample to firms with at least 7 patents per year on average (70 patents correspond to approximately the 10th percentile of the patent distribution). The coefficients are negative and both economically and statistically significant. The results are robust to defining the sample based on cutoffs of 80, 90, 100, or 115 patents over the 10 years of our sample, which correspond approximately to the 15th, 20th, 25th, 30th percentiles of the patent distribution. Observe that the higher the number of patents per year, and thus the less noisy our measure becomes, the stronger our results. Nevertheless, the coefficients are negative and of similar economic magnitude across all these different samples.

Allowing for China Entry

In Table C2, we re-estimate our baseline regressions using a time-varying measure of treatment. To this end, we construct an indicator variable $China_{i,t}$ that takes a value of 1 if a firm has a subsidiary in China in a given year t according to its 10K filings, and use it in the interaction with $Agreement_{(t>1999)}$. Moreover, we estimate an augmented specification where we interact an indicator for each year (d_t) with the $China_{i,t}$ dummy. In Table C3, we re-estimate specifications in Table 4 using the time-varying $China_{i,t}$ dummy. Results are very similar to our baseline analysis.

Not condition our sample on high-patenting firms

In Table C4, we repeat specifications in Table 4 without restricting our sample on high-patenting firms, which increases our sample size by 1,473 observations. This sample is the same as in Panel A of Table C1. Our results are robust to this alternative sample.

Normalize levels of process and product innovations by R&D and employment

In Table C5, we repeat specifications in Columns 3-4 of Table 4 for process innovations and in Columns 7-8 of Table 4 for product innovations, where we normalize the levels of process and product innovations by R&D expenditures (Columns 1-4) and by number of employees (Columns 5-8). Our results are robust.

Alternative Definitions

Our measures of innovation mix are constructed at the claim level. In Table C6, we show that our results are robust to using alternative definitions for our dependent variables. First, we use only independent patent claims to construct our measures, namely we exclude from the analysis claims that are subordinate to other claims. These (dependent) claims may be less important for the innovation. The coefficients in Columns 1-2 are negative and statistically significant at 5% and 10% level respectively.

Second, we use information at the patent level (instead of the claim level) to construct our measure of innovation mix. In Columns 3-4 of Table C6, we define process patents to be all patents with the first claim being a process claim (i.e. (purely) process patents and process-apparatus patents) and we construct the ratio dividing these with the total number of patents. In Columns 5-6, we instead define process patents to be all patents with at least one process claim (i.e. (purely) process patents, process-apparatus patents and product-method patents) which we then divide by the total number of patents. These alternative measures address concerns that there might be products that can be also used to lower firms' production costs, in which case our claim-based ratio would be under-representing the true mix of labor-saving innovations. Taking into account all combinations of process and product claims filed into patents, we consider an upper bound for labor-saving technological

innovations.

The results remain and the coefficient is negative and statistically significant across specifications. It is worth emphasizing, however, that a patent-based measure may be biased due to time-varying differences in patenting practices followed by different firms. This is possible as changes in ways the same number of patent-claims can be combined into patents can erroneously produce different numbers of product and process patents.

Next, we use an alternative source of identifying U.S. firms with Chinese subsidiaries before 1999 and we replicate our baseline results. This information is provided from the 2001 Survey of Foreign Invested Enterprises (FIEs) conducted by the National Bureau of Statistics in China. The survey covers FIEs set up by U.S. investors in China, which account for 75% of the total number of U.S. FIEs operating in China in 2001 as reported by China Statistical Yearbook 2002 (Du, Lu, and Tao, 2008). The survey is available only in Chinese and therefore needs to be translated into English and hand-matched to our Compustat sample. Our new $China_i$ indicator takes a value of 1 if, according to the survey, a U.S. firm has set up a subsidiary in China before 1999, and is 0 otherwise.³²

The results are presented in Table C7. Columns 1-2 repeat specifications of Columns 2-3 of Table 3 for the share of process innovation, Columns 3-4 repeat specifications of Columns 3-4 of Table 4 for process innovations, and Columns 5-6 repeat specifications of Columns 7-8 of Table 4 for product innovations. Our results remain, albeit weaker potentially due to the noise in matching the survey data to our Compustat sample. However, even the statistically insignificant results in Columns 2 and 4 have the right signs (p-value in Column 4 is .14) and are economically significant.

Alternative Samples

Our main identifying assumption is that treated and control firms are similar, except for the fact that treated firms have a presence in China prior to the 1999 U.S.-China

³²The survey provides information on the date the subsidiary is set up in China, and thus, to parallel our baseline analysis, we exclude firms which entered China after 1998. Our results remain primarily unchanged when including these firms.

bilateral agreement. Table 2 shows that there are no statistical differences across several observables. However, it is still possible that subtle differences between the two groups could lead to different ex-post outcomes. Thus, in this section we perform a matching analysis to minimize pre-treatment differences between the treated and control groups.

We match by size (as measured by sales) and industry (4-digit NAICS) in 1998, one year before the agreement is reached. Matching is done with replacement from the control sample and we keep the closest match. Table C8, Panel A presents the results on share of process innovation, process and product innovations. Across specifications we control for firm and year fixed effects and firm level controls. Columns 2, 4, and 6 also control for interacted industry and year fixed effects. Results are robust to this alternative sample and economic magnitudes are very similar to our baseline tests.

In Panel B, we restrict the sample to including control firms with Asian subsidiaries pre-treatment. To even more reduce differences between treated and control firms, we search for control firms with subsidiaries in Hong-Kong and Japan (the more developed, high-wage Asian countries) pre-treatment and exclude those from the analysis. The coefficients for the ratio and level of process innovation are significant at 1% level across specifications. These results, using alternative samples, alleviate concerns that pre-treatment differences in control and treated firms are driving our results.

Table C1: Robustness: Different sample cutoffs for defining high-patenting firms

This table reports results of regressions of the share of process innovations on treated firms following the 1999 US-China bilateral agreement as compared to a set of control firms, using different cutoffs to define high-patenting firms. Panel A includes all firms in the initial sample. Panel B includes all firms with 70 patents or more during our sample period (10th percentile). Panel C includes all firms with 80 patents or more during our sample period (15th percentile). Panel D includes all firms with 90 patents or more during our sample period (20th percentile). Panel E includes all firms with 100 patents or more during our sample period (25th percentile). Panel F includes all firms with 115 patents or more during our sample period (30th percentile). $China_i$ is a dummy which takes the value of 1 if a U.S. firm has a subsidiary in China in 1998, and is 0 otherwise. The sample period is 1995-2004. Firm-level controls include Market to Book and firm sales. Market to Book and Sales are defined as in Table 3. All regressions include firm and year fixed effects. Columns 3-4 also include interacted 2-digit SIC times year fixed effects. All variables are winsorized at the 1% level. Standard errors are clustered at the firm-level. *** indicates $p < 0.01$, ** indicates $p < 0.05$, and * indicates $p < 0.1$.

	Share of Process Innovations		
	(1)	(2)	(3)
	Panel A: All firms		
$Agreement_{(t>1999)} \cdot China_i$	-0.0148 (0.0111)	-0.0162 (0.0117)	-0.0129 (0.0122)
Obs.	3,872	3,201	3,201
	Panel B: Firms with 70 patents or more		
$Agreement_{(t>1999)} \cdot China_i$	-0.0205 (0.0114)*	-0.0226 (0.0116)**	-0.0194 (0.0120)*
Obs.	3,512	2,934	2,934
	Panel C: Firms with 80 patents or more		
$Agreement_{(t>1999)} \cdot China_i$	-0.0201 (0.0113)*	-0.0217 (0.0117)*	-0.0193 (0.0122)
Obs.	3,371	2,826	2,826
	Panel D: Firms with 90 patents or more		
$Agreement_{(t>1999)} \cdot China_i$	-0.0218 (0.0114)*	-0.0243 (0.0115)**	-0.0208 (0.0123)*
Obs.	3,127	2,624	2,624
	Panel E: Firms with 100 patents or more		
$Agreement_{(t>1999)} \cdot China_i$	-0.0248 (0.0113)**	-0.0270 (0.0115)**	-0.0252 (0.0124)**
Obs.	3,000	2,529	2,529
	Panel F: Firms with 115 patents or more		
$Agreement_{(t>1999)} \cdot China_i$	-0.0288 (0.0115)**	-0.0298 (0.0116)**	-0.0259 (0.0126)**
Obs.	2,742	2,335	2,335
Firm FE	Yes	Yes	Yes
Year FE	Yes	Yes	
Industry×Year FE			Yes

Table C2: Robustness: Allowing for China entry

This table reports results of regressions of the share of process innovations on treated firms following the 1999 US-China bilateral agreement as compared to a set of control firms. $China_{it}$ takes a value of 1 if a U.S. firm has a subsidiary in China in year t , and is 0 otherwise. The variable d_t is an indicator variable for year t . The sample period is 1995-2004. Firm-level controls include Market to Book and firm sales. Market to Book and Sales are defined as in Table 3. All regressions include firm and year fixed effects. Columns 3-4 also include interacted 2-digit SIC times year fixed effects. All variables are winsorized at the 1% level. Standard errors are clustered at the firm-level. *** indicates $p < 0.01$, ** indicates $p < 0.05$, and * indicates $p < 0.1$.

	Share of Process Innovations			
	(1)	(2)	(3)	(4)
$Agreement_{(t>1999)} \cdot China_{it}$	-0.0411 (0.0122)***	-0.0425 (0.0126)***	-0.0394 (0.0130)***	
$d_{1997} \cdot China_{it}$				-0.0082 (0.0149)
$d_{1998} \cdot China_{it}$				-0.0222 (0.0187)
$d_{1999} \cdot China_{it}$				-0.00194 (0.0200)
$d_{2000} \cdot China_{it}$				-0.0313 (0.0187)*
$d_{2001} \cdot China_{it}$				-0.0480 (0.0201)**
$d_{2002} \cdot China_{it}$				-0.0545 (0.0208)***
$d_{2003} \cdot China_{it}$				-0.0498 (0.0217)**
$d_{2004} \cdot China_{it}$				-0.0577 (0.0229)**
$China_{it}$	-0.0040 (0.0143)	0.0012 (0.0134)	0.0028 (0.0147)	0.0119 (0.0188)
Firm-level Controls		Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes		
Industry \times Year FE			Yes	Yes
R^2	0.72	0.76	0.80	0.80
Obs.	2,399	2,051	2,051	2,051

Table C3: Robustness: Allowing for China entry

This table reports results of regressions of the level of process (Columns 1-3) and product innovations (Columns 4-6) on treated firms following the 1999 US-China bilateral agreement as compared to a set of control firms. $China_{it}$ takes a value of 1 if a U.S. firm has a subsidiary in China in year t , and is 0 otherwise. The sample period is 1995-2004. Firm-level controls include Market to Book ratio and firm sales in Columns 2-3 and 5-6 and number of patents in all columns. Market to Book and Sales are defined as in Table 3. Patents is defined as in Table 4. All regressions include firm and year fixed effects. Columns 3-4 also include interacted 2-digit SIC times year fixed effects. All variables are winsorized at the 1% level. Standard errors are clustered at the firm-level. *** indicates $p < 0.01$, ** indicates $p < 0.05$, and * indicates $p < 0.1$.

	Process Innovations			Product Innovations		
	(1)	(2)	(3)	(4)	(5)	(6)
$Agreement_{(t>1999)} \cdot China_{it}$	-0.224 (0.0567)***	-0.235 (0.0584)***	-0.230 (0.0597)***	-0.0027 (0.0397)	-0.0039 (0.0391)	-.0273 (0.0410)
$China_{it}$	0.0612 (0.0745)	0.0368 (0.0670)	0.0648 (0.0708)	0.0586 (0.0487)	0.0170 (0.0498)	0.0503 (0.0536)
Firm-level Controls		Yes	Yes		Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes		Yes	Yes	
Industry \times Year FE			Yes			Yes
R^2	0.93	0.94	0.95	0.96	0.96	0.97
Obs.	2,399	2,051	2,051	2,399	2,051	2,051

Table C4: Robustness: Not conditioning on high-patenting firms

This table reports results of regressions of the level of process (Columns 1-3) and product innovations (Columns 4-6) on treated firms following the 1999 US-China bilateral agreement as compared to a set of control firms. The sample and regression specifications are the same as in Table 4, except that we do not require firms to be high patenting. All regressions include firm and year fixed effects. Columns 3 and 6 also include interacted 2-digit SIC times year fixed effects. All variables are winsorized at the 1% level. Standard errors are clustered at the firm-level. *** indicates $p < 0.01$, ** indicates $p < 0.05$, and * indicates $p < 0.1$.

	Process Innovations			Product Innovations		
	(1)	(2)	(3)	(4)	(5)	(6)
$Agreement_{(t>1999)} \cdot China_i$	-0.128 (0.0541)**	-0.124 (0.0566)**	-0.128 (0.0607)**	-0.0058 (0.0384)	0.0097 (0.0398)	-0.0188 (0.0422)
Firm-level Controls		Yes	Yes		Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes		Yes	Yes	
Industry \times Year FE			Yes			Yes
R^2	0.90	0.91	0.92	0.93	0.94	0.95
Obs.	3,872	3,201	3,201	3,872	3,201	3,201

Table C5: Robustness: Normalize by R&D and employment

This table reports results of regressions of the level of process and product innovations on treated firms following the 1999 US-China bilateral agreement as compared to a set of control firms. The sample and regression specifications are the same as in Table 4, except that process and product innovations are normalized by R&D expenses in Columns 1-4 and by number of employees in Columns 5-8. Columns 1-4 also control for the logarithm of R&D expenses as a proxy for R&D intensity. All regressions include firm and year fixed effects. Columns 2, 4, 6 and 8 also include interacted 2-digit SIC times year fixed effects. All variables are winsorized at the 1% level. Standard errors are robust and clustered at the firm-level. *** indicates $p < 0.01$, ** indicates $p < 0.05$, and * indicates $p < 0.1$.

	Log(Process/R&D)		Log(Product/R&D)		Log(Process/Emp.)		Log(Product/Emp.)	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
<i>Agreement</i> _($t > 1999$) · <i>China</i> _{i}	-0.0785 (0.0376)**	-0.0740 (0.0392)*	0.0114 (0.0373)	0.0030 (0.0357)	-0.174 (0.0584)***	-0.158 (0.0619)**	-0.0178 (0.0481)	-0.0180 (0.0498)
Patents	0.570 (0.0394)***	0.558 (0.0431)***	0.681 (0.0440)***	0.689 (0.0413)***	0.881 (0.0324)***	0.883 (0.0397)***	0.910 (0.0298)***	0.924 (0.0290)***
Firm-level Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes		Yes		Yes		Yes	
Industry × Year FE		Yes		Yes		Yes		Yes
R^2	0.91	0.92	0.94	0.95	0.94	0.95	0.95	0.96
Obs.	1,945	1,945	1,945	1,945	2,034	2,034	2,034	2,034

Table C6: Robustness: Alternative definitions of process and product innovations

This table reports results of regressions of the share of process innovations on treated firms following the 1999 US-China bilateral agreement as compared to a set of control firms. The sample and regression specifications are the same as in Table 3, except that we use alternative definitions for our dependent variables. Our measures are constructed based on independent claims in Columns 1-2, i.e. we exclude claims that are subordinate to other claims. In Columns 3-6, we use patent-level (instead of claim-level) information to compute our measure. In Columns 3-4, we define process patents as the number of process patents and process-apparatus patents and we divide that with the total number of patents to construct the share of process innovations. In Columns 5-6, we define instead process patents as the number of process patents, process-apparatus patents and product-method patents. All regressions include firm and year fixed effects. Columns 2, 4, and 6 also include interacted 2-digit SIC times year fixed effects. All variables are winsorized at the 1% level and standard errors are robust and clustered at the firm-level. *** indicates $p < 0.01$, ** indicates $p < 0.05$, and * indicates $p < 0.1$.

	Share of Process Innovations_Independent		Share of Process Innovations_Patent			
	(1)	(2)	(3)	(4)	(5)	(6)
$Agreement_{(t>1999)} \cdot China_i$	-0.0234 (0.0104)**	-0.0197 (0.0109)*	-0.0360 (0.0142)***	-0.0319 (0.0149)**	-0.0315 (0.0158)**	-0.0267 (0.0162)*
Firm-level Controls	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes		Yes		Yes	Yes
Industry×Year FE		Yes		Yes		Yes
R^2	0.73	0.77	0.77	0.80	0.79	0.82
Obs.	2,051	2,051	2,051	2,051	2,051	2,051

Table C7: Robustness: An alternative definition of treated and control groups

This table reports results of regressions of the share of process innovations (Columns 1-2), levels of process (Columns 3-4) and product innovations (Columns 5-6) on treated firms following the 1999 US-China bilateral agreement as compared to a set of control firms. The sample and regression specifications are the same as in Table 3, except that we use an alternative definition for $China_i$. $China_i$ is defined based on the 2001 survey of foreign invested enterprises conducted by the National Bureau of Statistics in China, which we linked to Compustat. All regressions include firm and year fixed effects. Columns 2, 4 and 6 also include interacted 2-digit SIC times year fixed effects. All variables are winsorized at the 1% level. Standard errors are robust and clustered at the firm-level. *** indicates $p < 0.01$, ** indicates $p < 0.05$, and * indicates $p < 0.1$.

	Share of Process Innovations		Process Innovations		Product Innovations	
	(1)	(2)	(3)	(4)	(5)	(6)
$Agreement_{(t>1999)} \cdot China_i$	-0.0235 (0.0128)*	-0.0104 (0.0141)	-0.131 (0.0595)**	-0.0922 (0.0634)	-0.0021 (0.0353)	-0.0363 (0.0380)
Firm-level Controls	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	–	Yes	–	Yes	–
Industry \times Year FE		Yes		Yes		Yes
R^2	0.80	0.94	0.95	0.96	0.96	0.97
Obs.	1,956	1,956	1,956	1,956	1,956	1,956

Table C8: Robustness: Alternative Samples

This table reports results of regressions of the share of process innovations (Columns 1-2), levels of process (Columns 3-4) and product innovations (Columns 5-6) on treated firms following the 1999 US-China bilateral agreement as compared to a set of control firms. The sample and regression specifications are the same as in Table 3, except that we perform the analysis in different samples. In Panel A, we match by size, proxied by sales, and industry (at the 4-digit NAICS level) based on pre-treatment values in 1998, one year before the agreement is signed. Matching is done with replacement and any firms that cannot be matched are dropped from the estimation. In Panel B, we include in the sample only control firms with Asian subsidiaries pre-treatment, excluding Hong Kong and Japan. All regressions include firm and year fixed effects. Columns 2, 4 and 6 also include interacted 2-digit SIC times year fixed effects. All variables are winsorized at the 1% level. Standard errors are robust and clustered at the firm-level. *** indicates $p < 0.01$, ** indicates $p < 0.05$, and * indicates $p < 0.1$.

	Share of Process Innovations		Process Innovations		Product Innovations	
	(1)	(2)	Panel A			
			(3)	(4)	(5)	(6)
$Agreement_{(t>1999)} \cdot China_i$	-0.0337 (0.0196)*	-0.0395 (0.0193)**	-0.161 (0.0833)*	-0.180 (0.0838)**	0.0014 (0.0576)	-0.0046 (0.0614)
Firm-level Controls	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes		Yes		Yes	
Industry \times Year FE		Yes		Yes		Yes
R^2	0.77	0.83	0.93	0.95	0.96	0.97
Obs.	1,357	1,357	1,357	1,357	1,357	1,357
Panel B						
	(1)	(2)	(3)	(4)	(5)	(6)
$Agreement_{(t>1999)} \cdot China_i$	-0.0371 (0.0135)***	-0.0362 (0.0137)***	-0.191 (0.0670)***	-0.204 (0.0716)***	0.0001 (0.0418)	-0.0220 (0.0465)
Firm-level Controls	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes		Yes		Yes	
Industry \times Year FE		Yes		Yes		Yes
R^2	0.74	0.80	0.94	0.95	0.96	0.97
Obs.	1,627	1,627	1,627	1,627	1,627	1,627