Innovation Responses to Import Competition*

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Abstract

How does trade liberalization that raises a country's import competition affect the innovative activity of its firms? We exploit the strong growth of Chinese exports resulting from China's entry into the World Trade Organization in 2001 as a competitive shock to, specifically, Mexican manufacturing firms. Innovation is captured through information on the adoption of detailed firm level production techniques such as just in time inventory methods, quality control measures, and job rotation among the Mexican firms. Our results indicate that China's rise in global trade did not affect by much Mexico's rate of innovation, which contrasts with the substantial gains that others have found in the case of bilateral liberalizations. At the same time, there is a striking heterogeneity in the responses across firms for different productivities, with productive firms innovating more and less productive firms innovating less, which leads to positive selection in that initial differences in firm performance are sharpened by the advent of new competition. We discuss the implications of these findings for theories of trade and innovation.

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1 Introduction

Trade liberalization in form of foreign market access improvements rarely encounters domestic political opposition because it means higher exports and employment for domestic firms. Economists have long supported the dismantling of trade barriers on efficiency grounds, noting additional gains recently through the reallocation of firms' market shares and increased incentives to innovate, among others (Pavcnik 2002, Melitz 2003, Bernard et al. 2003, Aw, Roberts, and Winston 2007, Costantini and Melitz 2008, Verhoogen 2008, Lileeva and Trefler 2010, Bustos 2010). Given these benefits from improved foreign market access, it is natural to ask how they compare with the benefits from improving domestic access to foreign firms.

This paper addresses this question by examining innovation of Mexican firms in response to increased competition from China between the years 1998 to 2004. China's entry into world trade was the largest trade shock during the last 30 years.[1] By becoming a member of the World Trade Organization (WTO) in 2001, China gained new market access, and her already-high rates of export growth accelerated. Figure 1 shows the increasing presence of China on the world markets, with a particular steep slope in the years after 1998. Mexico was among the countries most strongly affected, because Mexico had substantial overlap with China in terms of product range, and the location of Mexico next to the United States has made it particularly vulnerable to competition from China. In comparison to its imports from China, Mexico's exports to China over this period were trivial.

This setting yields an unparalleled opportunity to examine the innovative behavior of firms under the threat of competition. Innovation has many dimensions, and relatively little is known on which ones are most important. Some emphasize inventory management while others the control of the production process, other observers see workers as the crucial element while a fourth group focuses on computers and equipment. This paper provides evidence on this and other specific forms of innovation by Mexican firms as they faced new import competition from

[1]See Krugman (2008), Bloom, Draca, and Van Reenen, and Winters and Yusuf (2007).

China. This affords us a new look into the black box of firm-level innovation in response to competitive shocks.[2]

Our main findings are as follows. First, the aggregate level of innovation of Mexican manufacturing firms did not change much with the new import competition from China. In contrast, earlier studies have often found substantial overall effects (Pavcnik 2002, Bloom, Draca, and Van Reenen 2009, Lileeva and Trefler 2010). Our second, and related finding is that the aggregate effect masks a striking heterogeneous response across firms of different productivity. We find that relatively productive firms innovate more in response to the China trade shock while less productive firms innovate less. Import competition sharpens the difference between strong- and weak performing firms because it leads to innovation that amplifies the initial difference. This is a positive dynamic selection finding.

Third, there is little evidence that the innovation strategies of Mexican firms can be explained by market size reallocations. The sales growth of the firms that innovate during the period of China's entry into the WTO is similar to the sales growth of firms that do not innovate. While a market-size explanation of firm-level innovation is not supported by our results, they are consistent with productive firms having relatively more to gain from innovation than less productive firms, as, for example, in the model of Aghion, Harris, Howitt, and Vickers (2001).[3] We also find that a high degree of intermediate good imports from Asia, foreign ownership, and a skilled labor force is conducive to innovation in the face of import competition.

The gains from trade liberalization is a central question in international economics, and this paper sheds new light on innovation gains in this context. It has long been argued that trade liberalization can affect a country's rate of innovation, and analysis of the detrimental impact of import substituting trade strategies adopted by many less developed countries after World War II was early evidence of this (Krueger 1975, Bhagwati 1978). Our work builds on and extends

[2]The terms firm and plant are used interchangeably in this paper; the evidence below is on plants.

[3]In Aghion, Harris, Howitt, and Vickers (2001), competition will provide greater incentives to innovate for high- compared to low-productivity firms because conditional on innovation, a high-productivity firm can win out against the foreign competitor in a limit pricing contest whereas the low-productivity firm cannot.

this research by emphasizing heterogeneity as a determinant of firms' innovation choices (see surveys by Tybout 2003 and Redding 2010).

Our approach is distinct in two ways. First, we examine innovation in the sense of particular organizational forms and production techniques. The specific way in which a firm controls product quality, optimizes its inventory, and manages its operations more generally explain much of the variation in economic performance across firms, a finding emphasized in the business literature and more recently also by economists (Womack, Jones, and Roos 1991 and Bloom and Van Reenen 2007, Syverson 2010, respectively). In the context of trade liberalization, studies on the adoption of specific firm techniques are extremely rare; an exception is Schmitz (2005) who presents a case study on the abolition of restrictive work practices among North American iron ore producers. Information on the introduction of computer systems needed for Just-in-Time techniques is presented in Lileeva and Trefler (2010), while Dhingra (2011) employs direct evidence on production process innovations in analyzing trade-offs faced by multi-product firms.

Comparatively little is known on how firms change their organizational structure and their operations management in reponse to new sources of competition. The main advantage of analyzing specific innovations is its potential for better understanding the factors determining overall firm performance. When firm innovation is broken down into its constituent parts, this will provide more information on which are the truly crucial elements, and it also sheds new light on how individual choices fit together to form the overall firm strategy. This information should prove valuable in understanding the import and export behavior of firms. In addition, particular innovations may have quite different implications of trade liberalization on labor markets and the economy as a whole. If innovation is mainly in form of improved inventory management we would expect labor demand to become less skill biased than if innovation is mostly in form of machinery replacing unskilled labor, for example. In contrast, a focus on productivity changes does not give as much information, also because the productivity changes that can be measured in practice pick up changes in market power (Foster, Haltiwanger, and Syverson 2008), product mix (Bernard, Redding, and Schott 2010, Mayer, Melitz, and Ottaviano 2010), and factor market distortions (Hsieh and Klenow 2010) as well.

Second, we examine innovation responses to trade liberalization when the size of the market is shrinking. There is a large literature on how an expanding market size might increase innovation because innovation is complementary to the firm's decision to export (Yeaple 2005, Verhoogen 2008, Costantini and Melitz 2008, Atkeson and Burstein 2008, Lileeva and Trefler 2010, and Bustos 2010),[4] but this argument does not apply in the case of new import competition because market size is generally shrinking. Innovation in the face of new import competition must be driven by something other than increases in firm scale, and in this respect our research relates to research on the impact of changes in domestic competition and FDI entry (see Holmes and Schmitz 2010 and Aghion, Blundell, Griffith, Howitt, and Prantl 2009, respectively). Arguably, from a policy perspective the innovation response to unilateral trade liberalization at home is just as important as the response to bi- or multilateral liberalizations.

A recent contribution on the impact of import competition from China is Bloom, Draca, and Van Reenen (2009).[5] These authors emphasize that the contribution of trade in generating wage inequality in rich countries is larger than generally presumed by showing that this competition induced European firms to increase spending on computers, which had a positive effect on the skill premium. Our work differs because instead of technology investments we analyze specific organizational changes of the firms, and moreover, in contrast to Bloom, Draca, and Van Reenen (2009) we find strong heterogeneity in firms' innovation responses to competition, increasing for some and decreasing for other firms.

The remainder of the paper is as follows. We start out by introducing the empirical approach

[4]Similar market size effects are seen in the case of FDI; in particular, technology spending of firms that decide to supply Wal-Mart in Mexico (which increases the market size of the supplier) goes up relatively that of non-Wal-Mart suppliers (Iacovone, Javorcik, Keller, and Tybout 2010).

[5]Other research on the impact of China's recent entry into global trade includes Utar and Torres Ruiz (2010) and Iacovone, Rauch, and Winters (2010). The latter examine the impact of China's trade on the market shares of firms and products in Mexico, which is complementary to our emphasis on innovation. Utar and Torres Ruiz (2010) study productivity changes among Mexican export processing firms (*maquiladoras*) using familiar methods. *Maquiladoras* are also included in our sample below.

in section 2. The various forms of innovation analyzed in this paper are introduced in section 3. This section also covers their basic features in our sample of Mexican firms, which guides the empirical analysis. A description of our other data is also in section 3. All empirical results are discussed in section 4, while section 5 provides some concluding discussion.

2 Estimating the relationship between innovation and competition

The empirical approach is this paper is straightforward. We relate firm-level innovation to a variable that captures the change in import competition faced by Mexican plants after China's entry into the World Trade Organization:

$$y_{i(j)t} = \beta_0 + \beta_1 \Delta comp_{jt} + \gamma X + u_{i(j)t}. \tag{1}$$

Here, $y_{i(j)t}$ denotes a specific type of innovation of firm i, for example the adoption of Just-in-Time (JIT). Firm i is observed in year t, and each firm belongs to a particular six-digit industry j;the variable $\Delta comp_{jt}$ is the change in competition for industry j at time t, the term X is a vector of other observable determinants of $y_{i(j)t}$, and $u_{i(j)t}$ is an error term. Our sample is a balanced panel of firms with two years of observations, for 1998 and for 2004, which in equation (1) is estimatad as a long-difference regression. In the case of JIT as the dependent variable, for example, $y_{i(j)t}$ is equal to one if the firm has introduced JIT between the years 2000 and 2004, and zero otherwise.[6] The goal is to consistently estimate β_1 as the impact of competition changes on innovation.

There are reasons to believe that $\beta_1 < 0$, for example because increased competition dissipates rents that are necessary to sustain innovation (Schumpeter), and there are other reasons that would give $\beta_1 > 0$, for example because increased competition increases managerial effort

[6] We choose the years 2000 to 2004 because by the end of the year 1999 it had started to become clear that China would enter the WTO soon (official accession was in the year 2001).

(Schmidt 1997) or it may lower product line switching costs (Holmes, Levine, and Schmitz 2008).[7] At this point we are agnostic about the sign of β_1,the competition effect on innovation.

We will also generalize equation (1) by letting the impact of competition on innovation depend on characteristics of the firm. Denoting a specific firm characteristic by $q_{i(j)t}$, the extended estimating equation becomes:

$$y_{i(j)t} = \beta_0 + \beta_1 \Delta comp_{jt} + \beta_2 q_{i(j)t} + \beta_3 \left(q_{i(j)t} \times \Delta comp_{ijt} \right) + \gamma X + u_{i(j)t}. \tag{2}$$

Equation (2) includes the linear term in $q_{i(j)t}$ so that β_3 captures only the differential effect from changes in competition. The parameter β_3 is of key interest, because $\beta_3 \neq 0$ would indicate that the competition effect on innovation varies with the firm characteristic. Several firm characteristics are prime candidates for $q_{i(j)t}$. In line with a large body of trade research emphasizing exogeneous heterogeneity in productivity, we will begin with the productivity of the firm in the year 1998, prior to China's entry into the WTO.

Going beyond productivity, the analysis will be extended to other initial (year-1998) determinants, such as the skill composition of the firm's labor force. Moreover, we will also examine whether contemporaneous changes in firm characteristics between 1998 and 2004 are related to specific firm innovation between the years 1998 and 2004. On the one hand, it might be that the introduction of specific innovation and, say, the training of the labor force are complementary activities. On the other, if both activities eat up firm resources (and the firm is partially credit constrained), or innovation and labor training are alternative ways of tackling new import competition, the relationship between innovation and other contemporaneous firm changes may be negative.

Consistent parameter estimation in (1) and (2) requires that a number of issues are addressed.

[7]The theoretical literature of the impact of competition on innovation is covered in Bloom, Draca, and Van Reenen (2009) and Holmes and Schmitz (2010).

There is the possible endogeneity of the change-in-competition variable $\Delta comp_{jt}$ as well as measurement error in our dependent variables, $y_{i(j)t}$. Moreover, several of our dependent variables, for example Just-in-Time (JIT), take on only the value of zero and one. We will therefore estimate the equations not only with linear probability models using least squares but also with probit models using maximum likelihood. These issues will be discussed below.

The following section discusses the data sources and the definition of the innovation variables.

3 Data

This paper employs data provided by *Instituto Nacional de Estadística y Geografía* (INEGI), a Mexican statistical agency. We use surveys of manufacturing firms from the years 2005 and 1999, which cover information for the years 2004 and 1998. These surveys of the *Encuesta Nacional de Empleo, Salarios, Tecnología y Capacitación* (ENESTyC), provide information on a large range of characteristics in the area of technology, employment, and labor training salaries, in addition to basic information on sales, investment, and age of the firm. The survey includes all Mexican firms with more than 100 employees, and uses a sampling procedure that ensures representativeness to include smaller firms. The data attaches a unique identified to each firm that remains the same over time, which allows us to follow firms over time.

In the section on firm organization, the ENESTyC questionnaires ask about the existence (and in 2005 also the year of introduction) of a number of firm techniques. These techniques define key elements of the operations management of the firm, which is the business function responsible for planning, coordinating, and controlling the resources needed to produce a firm's product (Reid and Sanders 2005). Most of the specific techniques that we will study are part of operations management concepts that became known in the 1980s and are sometimes collectively referred to as lean manufacturing. These ideas originated mostly in Japan, specifically with the car maker Toyota. They gained rapidly influence in business circles, and it is reasonable to expect that these concepts were well-known in Mexican firms towards the end of the 1990s.

While the concepts are related, each of them defines a particular aspect of the techniques firms are employing. The following gives a list of techniques, followed by a brief description of the key elements of each technique: (1) Total Quality Management; (2) Statistical Quality Control; (3) Quality Control; (4) Just-in-Time System; (5) Re-organization; and (6) Job Rotation.[8]

(1) **Total Quality Control**: Total Quality Control, or Total Quality Management (TQM), is an integrated effort designed to improve quality performance at every level of the organization. TQM focuses on proactively identifying root causes of reoccurring problems, correcting them at the source, where customers ultimately determine what is important (customer-driven quality). Key methods include continuous improvement, employee empowerment, understanding quality control tools, and the formation of work groups acting as problem-solving teams (so-called quality circles).

(2) **Quality Control of Production**: The question whether product quality is meeting the pre-established standards. Quality Control uses a number of statistical methods, in particular (i) Descriptive statistics, (ii) Statistical process control, which is to determine whether a process is performing as expected, and (iii) Acceptance sampling, where entire batches of products are accepted or rejected by only inspecting a few items.

(3) **Just-in-Time System**: The goal is to get the right quantity of goods to the right place exactly when they are needed. Key ideas are (i) to eliminate unsynchronized production, unstreamlined layouts, and unnecessary material handling (referred to as waste); (ii) to take a broad view of operations so that the system, not individual tasks, are optimized; (iii) to make operations simpler, with fewer steps (also less error prone); and (iv) to improve visibility so that waste can be detected. Methods include so-called Kanbans and pull production systems, quick

[8] The following descriptions draw on a number of sources on operations management, in particular Reid and Sanders (2005).

setups and small lots, uniform plant loading, and flexible resources such as general-purpose equipment and multi-trained workers.

(4) **Re-Organization**: The re-organization of the work facility in terms of equipment, machinery, and installations. Re-organization can improve the physical arrangement of resources within a facility. Standard forms of facility layout are (i) process layouts, which groups similar resources together, and (ii) product layouts, which is designed to produce a specifc product efficiently. It is central to have workstations in close physical proximity to reduce transport and movement as well as streamline the flow of material. A key method is so-called cellular manufacturing. Improved work facility layout also reduces the probability of work risks, thereby reducing downtime.

(5) **Job Rotation**: Job rotation is a central part of the worker-related aspects of modern operations management. It recognizes that in addition to the advantages that labor specialization brings, it can also carry high costs in terms of high absenteeism, high turnover rates, and high number of employee grievances filed, at the same time when workers are dissatisfied because they see little growth opportunity, control over work, room for initiave, and intrinsic satisfaction in their work. Job rotation aims at changing that by shifting the worker through several jobs to increase understanding of the total process, together with the necessary skill training. This may also lead the worker to make better decisions at their own departments and to increased communication across various different departments of the firm.

(6) **Statistical quality control**: The questionnaires by INEGI specify that in this question the surveyor asked for the installation of any system of quality assurance, by which products are cross checked along certain check points on the production chain if their quantity and quality matches predefined standards.

In Table 1 we provide summary statistics on these innovation measures before 1998, and in the period from 1998 to 2004. 15 percent of plants in our sample introduced Just in Time before 1998, and 14 more percent of the remaining plants introduced this system in the years

2000-2004, making Just in Time the least adopted innovation in our analysis. More firms had adopted Total Quality Control, which as used by 50 percent of plants before 1998, with new introductions of around 20 percent of the remaining plants from 2000 to 2004. There is generally a positive correlation between these measures of innovations, although with a range of 0.18 to 0.42 this correlation is not particularly strong.

This concludes the discussion of the innovation measures employed in this paper.

In addition to these variables, the ENESTyC surveys also include variables that are relevant for innovation strategies of firms, in particular whether a firm exports, what fraction of its sales it exports, whether a firm imports part of its materials and intermediates, and if so from where; whether a firm is foreign owned, and at what percentage; the skill composition of the firm's labor force, as well as the extent of worker training that was performed. In addition, the surveys cover variables that measure technology investment inputs, such as R&D expenditures and other activities affecting the technological capabilities of the firm (such as technology purchases, equipment purchases, and indicators of process and product innovation). Our analysis will focus mainly on the adoption of specific firm techniques such as Just-in-Time, for reasons laid out above.

Table 2 gives summary statistics of these variables. Sales of plants in our sample increased considerably in the six years studied, from 311 to 540 thousand pesos, while total employment for the plants in our sample decreased in mean and median. The share of expenditures spent on R&D was relatively low in both years, with the median plant not spending on research in both years, which is typical for large samples of firm level data.

Our measure of import competition is based on the actual market share gains of Chinese exporters between the years 1998 and 2004.[9] While we are interested in the response of Mexican firms to Chinese competition, we recognize that Chinese market share gains in Mexico are potentially endogenous to the performance of the Mexican firms themselves. To address this

[9] We are in the process of adding policy measures–the change in tariffs–for a subset of industries as additional measures of changes in import competition.

issue, we employ information on Chinese market share gains in the United States instead of Chinese gains in Mexico over this period. By exploiting evidence on the competitive strength of China in a different, much larger though closely related market, we are more plausibly examining an exogenous shock to the Mexican manufacturing sector.

The import competition variable is the 1998-to-2004 change in the imports from China in the United States, relative to all US imports, for narrowly defined industries. We merge the survey information with the well known international trade data from COMTRADE employing the concordance of Iacovone, Rauch, and Winters (2010). This links the Mexican plant data at the six-digit level (CMAP 6) to the COMTRADE trade data according to the Harmonized System (HS) classification.

The following section presents our empirical findings.

4 Empirical Results

4.1 Innovation and Competition

We now turn to estimating the effect of competition from China on the innovative behavior of Mexican plants. A simple estimation strategy is adopted in which measures of innovation after China's entry into the WTO in 2001 are related to competition from China and a number of control variables. Dropping the time subscript, the equation we estimate for the results in Table 3 is:

$$y_{i(j)} = \beta_0 + \beta_1 \Delta comp_j + \gamma X + \varepsilon_{i(j)}, \tag{3}$$

where $y_{i(j)}$ is an innovation outcome variable of plant i in the six-digit industry j in the year 2004, β_0 a constant, $\Delta comp_j$ a measure of competition from China at the six-digit level, X a matrix of control variables such as the age of a plant, the distance to the U.S. border, a dummy for plants in Mexico City, and a matrix of two digit industry fixed effects. Throughout the reported results we apply robust standard errors, which we cluster at six digit industry level (the level at which competition varies).

As noted above, we are concerned that the observed degree of import penetration of China in Mexico is endogenous. One possibility is that Chinese firms make greater inroads into the Mexican market whenever the Mexican competitors are particularly weak. To address endogeneity issues, we adopt two approaches. First, instead of the Chinese import shares in Mexico we employ Chinese import shares in the United States (US) and in the European Union (EU) as proxy variables. Second, more formally we use the Chinese import share gains in the US and in the EU as instrumental variables (IV) for the Chinese import shares in Mexico. The rationale for this IV approach is that while China's export success in the US and in the EU is positively related to Chinese market share gains in Mexico (correlation of about 0.6), there is little reason to believe that Chinese export gains in the US and EU are endogenous to the innovation behavior of Mexican firms.

Table 3 shows results for estimating equation (3) with six different innovation measures as dependent variables. In the top panel, the measure of competition is the change in China's import shares in Mexico. Specifically, in column (1) $y_{i(j)}$ is equal to one if the plant adopted Just-in-Time (JIT) techniques between the years 1998 and 2004, and zero otherwise. The competition variable is the change in the import share from China in Mexico between 1998 and 2004 (6-digit level). The other included variables are, first, the geographical distance of the plant to the United States border which is a determinant of the US orientation (especially the export-processing *maquiladoras*). We also control for whether a plant is located in Mexico City or not, and a set of age indicators (age greater than 10 years is the excluded category). We also include two-digit industry fixed effects which capture broader industry trends. Estimation method is OLS, with p-values based on robust and clustered (6-digit industry) standard errors reported in parentheses.

According to these results the increase of import competition from China is associated with lower levels of innovation for Quality Control and Re-Configuration, while innovation in form of other management techniques is unaffected. There is no evidence from this for an impact of competition on innovation that holds across the board for all plants. In addition, the control variables are rarely significant.

In the second panel of Table 3, we proxy for the impact of Chinese exports in Mexico by their market share gains in the US and in the EU. The rate of innovation among Mexican firms is not related to Chinese market share gains in the US. There may be reason to prefer the EU proxy because Mexican firms are overwhelmingly exporting to the US, and therefore by using the market share gains of Chinese firms in the US one may pick up third-market effects. In the case of the EU the evidence is mixed, with the coefficient β_1 being significantly negative in two thirds of the cases. To the extent that the coefficient is negative, this is also in contrast to the positive impact of competition on performance that has been found earlier in other studies.

Finally, in the lower part of Table 3 we show IV results where the import share gains of Chinese exporters in Mexico is instrumented by their gains in the US and in the EU, respectively. Note that in both cases, the first-stage F-statistics suggest that the instrument is powerful. While in the second stage many of the point estimates are negative, only in the case of the EU instrument are they significant, and also here only half of the time. Overall the IV results suggest that innovation among Mexican firms across the board is neither significantly stimulated nor stunted by new import competition from China.

In the following section, we consider the possibility that the innovation response of plants is shaped by specific plant characteristics.

4.2 Heterogeneous Innovation Responses To Competition

4.2.1 Productivity Heterogeneity

We begin our analysis by examining the role of exogenous productivity differences across firms, which has been highlighted as an important determinant of firm behaviour in a trade context in recent work (see the overview in Redding 2010). Our measure of productivity is a dichotomous variable that equals one if a firm has a labor productivity, defined as sales over employment, in the year 1998 that is higher than the median of the three-digit industry to which the firm belongs, and zero otherwise.[10] The estimation equation follows (2) from above, which is reproduced here for convenience:

$$y_{i(j)} = \beta_0 + \beta_1 \Delta comp_j + \beta_2 q_{i(j)} + \beta_3 \left(q_{i(j)} \times \Delta comp_j \right) + \gamma X + u_{i(j)}. \tag{4}$$

Equation (4) represents a cross-sectional relationship for the years 1998 to 2004, and consequently we have dropped time subscripts. The variable $q_{i(j)}$ is the indicator of high productivity in the year 1998 ($q_{i(j)} = 1$), while $q_{i(j)}$ is equal to zero if firm i (in six-digit industry j) had a relatively low productivity in 1998. According to equation (4), β_1 gives the relationship of competition and innovation for firms with low initial (1998) productivity, while $(\beta_1 + \beta_3)$ gives the effect for firms with high initial productivity. Results are shown in Table 4; on top are OLS results with the Chinese import share change in EU as independent variable, while on the bottom we report results for the corresponding IV specification.[11]

Column (1) shows the results of estimating (4) with Just-in-Time (JIT) as the dependent variable. First, note that the coefficient on initial productivity, β_2, is close to zero. Because there is no evidence that high productivity raises the probability of JIT adoption, strong past

[10] We define productivity relative to the three-digit industry to ensure that both the high- and the low-productivity firm groups have firms from all industries; Lileeva and Trefler (2010) have recently adopted a similar approach.

[11] We also henceforth focus on the set of firms that by 1998 had not yet adopted a certain technique (potential switchers). This is useful as it reduces the noise in the analysis.

performance –which led to high productivity by 1998– does not appear to necessarily translate into higher rates of innovation.

There is, however, a key distinction between high and low productivity firms in terms of their innovative response in the face of import competition. JIT adoption rates of low productivity firms fall when they are hit by competition, whereas JIT adoption rates of high productivity firms do much less so. The sum of the point estimates $\beta_1 + \beta_3$ is close to zero (-0.07 in the IV case). Hence, while the typical firm with low productivity significantly reduces innovation, the behavior of high productivity firms hardly changes. The same pattern is estimated for innovation in form of Re-Configuration, see column (4).

Further, we estimate that the adoption of Quality Control and Total Quality Management (TQM) falls for all firms in the face of import competition (columns (3) and (4)), although also here there is a striking difference in the magnitudes: low productivity firms reduce innovation rates by more than high productivity firms. Moreover, competition splits the qualitative response of firms in their adoption of Job Rotation: it increases for high productivity firms while it decreases for low productivity firms. Overall, the arrival of Chinese import competition appears to bi-sect the distribution of Mexican firms, which are sorted into firms that continue to innovate or not on the basis of their past performance.[12]

While these results point to a striking difference as to how strong versus weak performing firms react to import competition in terms of innovation, before drawing any conclusions we have to address a number of issues. First, the innovation measures are limited dependent variables, taking on the value of 0 or 1, so that applying OLS might yield misleading results. We therefore consider probit regressions as an alternative. The probit results are given in Table 5 along with the OLS results from Table 4 (marginal effects are reported for the probit). We see that for these five innovation measures, the magnitude and significance of how the innovation response to competition differs between high and low productivity firms is remarkably similar in the probit and OLS regressions.

[12]The relatively imprecise estimates for Statistical Control (column (6)) are consistent with this assessment.

Second, it may be that the parametric form of the interaction variable $q_{i(j)} \times \Delta comp_j$ affects our results in a particular way. To address this issue, we have estimated the relationship between innovation and changes in import competition separately for low and for high productivity firms. The results are given in Table 6. For a given innovation measure, the first column reports the results for high productivity firms (as of 1998), and the second column shows results for the same regression for the low productivity firms. Comparing the estimated impacts of import competition, the results from this less parametric approach are quite similar to the interaction variable-regressions shown in Table 4.

Specifically, while all point estimates for low productivity firms are negative this is not the case for high productivity firms. Moreover, even when the impact of competition lowers innovation for all firms, the magnitude of this effect is larger for low productivity than for high productivity firms. As shown in Figure 2 which graphs the point estimate and 90% confidence intervals for the techniques of Table 6 separately for high and low productivity firms, the difference is significant in some of the cases.[13]

Third, we have further examined the role that our competition measure plays for these results. In the upper panel of Figure 3, we show the difference for the low and high productivity firms for four different measures of competition. On top is the change in Chinese imports in the US, for which we have shown results above, followed by the 1998 level of the Chinese import share in the US. Along the lines of Pavcnik (2002) and others, the initial level of imports may be a good predictor of which industries are particularly threatened by future increases in import competition. The lower two graphs are for the change of China's import share in Mexico, while the fourth set of results is for the level of China's import share in Mexico in the year 1998.

Figure 3 shows that the difference in the innovative response of low and high productivity firms to import competition exists independent of which particular measure of competition is employed. The figure indicates that the difference between low and high productivity firms is strongest for the 1998 US level variable. For the 1998 Mexican level variable the difference is

[13] Underlying Figure 2 are the results from panel 2 (imports in the US using OLS).

less clear, presumably because Chinese import shares in Mexican six-digit industries in 1998 were still quite low across the board. Moreover, we confirm the strong difference between low and high productivity firms if we base the competition measure on Mexican absorption (imports plus production minus exports) instead of Mexican imports.

We conclude that the finding that productive firms innovate more in response to the China trade shock while less productive firms innovate less is robust in a number of ways. It means that import competition sharpens the difference between strong- and weak performing firms because it leads to innovation that amplifies the initial difference. We emphasize that we find little evidence that strong firms generally innovate more, but rather that import competition triggers this response leading to positive dynamic selection.

Moreover, the response difference of strong versus weak performing firms can only be explained in a framework that allows for a non-monotonic relationship between innovation and competition. One possibility is the escape-competition effect modeled by Aghion et al. (2001). In contrast, while a Schumpeterian argument may explain why low productivity firms innovate less it is inconsistent with high productivity firms innovating at the same time more. Alternatively, if increased competition increases innovation by reducing agency problems, there must be another explanation for why low productivity firms reduce innovation in the face of import competition from China.

How important is competition in accounting for the observed patterns of innovation? To answer this question, we compute the 1998 market share-weighted mean coefficient of competition, denoted as $\bar{\beta}_{comp}$.[14] Table 7 shows these results for six innovation measures in the first column. The mean coefficient is positive for all techniques even though the innovation response of many firms is negative, because high performing firms have higher market shares than low performing firms. The average change in the Chinese import share, $\Delta comp_j$, is about 0.06, whereas the observed mean adoption rates, $\bar{y}$, are reproduced from Table 1 in column 2 of Table 7. Computing the role of competition as $(\bar{\beta}_{comp} \times \Delta comp_j)/\bar{y}$, we find that competition accounts for around

[14]The following calculations are based on the estimates of Table 6, part 2 (US import shares).

6% of all innovation, ranging from 1% for Re-organization to 13% for Just-in-Time techniques. On the right side of Table 7, we repeat this analysis for the sample of high productivity firms, and competition accounts for about 10% of all innovation performed by these firms.

The following analysis considers additional determinants of innovation that might explain heterogeneity in innovative behaviour in response to import competition.

4.2.2 Beyond Productivity: What is Driving Heterogeneous Innovation Responses to Competition?

We are interested in understanding what lies behind the heterogeneous responses to import competition in Mexico around China's entry into the WTO. A well-established finding in trade is that firms with high productivity are different from firms with low productivity in many respects, for example high productivity firms tend to be larger, they are more likely exporting, and they tend to have a more skilled labor force. This leaves open the possibility that productivity and, say, the skill level of the labor force are jointly determined, or that the skill of the workers in fact is what makes the firm more productive. In the present context, we pursue these questions by asking whether there are other firm characteristics that can explain innovation differences in response to competition.

We do so by augmenting the estimation equation (4) from above with other determinants, $g_{i(j)}$, that help to account for the innovation response to competition:

$$y_{i(j)} = \beta_1 \Delta comp_j + \beta_2 q_{i(j)} + \beta_3 \left(q_{i(j)} \times \Delta comp_j\right) + \beta_4 g_{i(j)} + \beta_5 \left(g_{i(j)} \times \Delta comp_j\right) + \gamma \tilde{X} + u_{i(j)}. \quad (5)$$

The factors $g_{i(j)}$ that we consider in the following are as follows. First, firms may have made prior investments that affect their ability to react to new import competition, just as firms prepare their entry into the export market (e.g. Hallward-Driemeier, Iarossi, and Sokoloff 2005). An important step that firms can take is to satisfy international quality standards such as ISO 9000. Below we examine whether firms that had achieved ISO 9000 certification by the year 1998 show an innovative response that is different from firms that were not ISO 9000-certified. Second,the introduction of new management techniques may be faciliated by the existence of capital equipment. One reason may be that, in particular, advanced capital equipment is a general sign of the (high) quality of the firm. Another is that certain capital equipment is conducive to the introduction of particular management techniques. In the analysis below we condition the firms' response to import competition on the share of industrial robots in their total stock of equipment of the year 1998.

Several of the management techniques that we consider require that workers are newly trained on-the-job. It is thus reasonably to believe that the likelihood of the adoption of new management techniques may be dependent on whether a particular firm performs worker training on a regular basis. Below we will employ information on the extent of each firm's worker training in 1997 and 1998 to shed new light on this. The measure is the hours of training per worker for a particular blue-collar worker type (*obreros especiales*).

The innovative behavior of firms may also be related to the way they make decisions on the acquisition of new technology. In addition to own research and development, firms may obtain new technology from their headquarter (if they are part of a larger firm), they may hire consultants that help to implement it, or they may purchase new technology at arm's length and implement it themselves. While the cost of technology obtained from the headquarter may be low, it may not be as well suited to the firm's needs as when the firm decides to purchase the technology itself at arm's length. Moreover, if technology acquisition is primarily at arm's length it indicates decentralized decision making about technology choices, especially for firms that are part of a larger group of firms. The variable we employ below is equal to one when technology acquisition is mostly in form of purchases at arm's length, and zero otherwise. Alternative modes of technology acquisition are obtaining it (i) from the headquarters, (ii) with the help of external consultants, or (iii) through conferences and books.

Two additional pieces of information will be employed. One, we ask whether the existing level of profitability of a firm, as measured by its price-cost margin in the year 1998, affects its innovative response to new import competition. High profitability could be conducive to future innovation if it indicates that the firm has the revenues to pay for any up-front cost of innovation, especially in the case where firms face partial borrowing constraints. Two, a firm that enjoys high margins may be better placed to weather the competition shock without actually having to innovate. We also employ information on whether firms buy their equipment primarily domestically or not. Firms that import equipment may benefit from the higher quality that this equipment may have. Moreover, firms that import equipment may also benefit from new and cheaper sources of equipment, including from China. In the latter case firms may in fact gain from lower input costs, as opposed to face a lower price for their final good due to the new imports.[15]

Results for these variables are shown in Table 8. For each of the firm characteristics $g_{i(j)}$, we report results with the import share gain in the EU, first the OLS and then the IV estimation. The specific form of innovation under consideration is listed near the top of each column. Specifically, column (1) of Table 8 gives the OLS results for the impact of ISO 9000 certification, in addition to productivity, for the adoption of Just-in-Time techniques, and column (2) gives the corresponding IV estimates. New import competition from China tends to reduce the adoption of JIT among Mexican firms (coefficient of about -1 on $\Delta comp_j$ in column (2)). What matters whether firms respond to this by adopting JIT or not is not so much firm productivity but whether the firm had become ISO 9000-certified: firms that did have an increased probability of JIT adoption ($\beta_1 + \beta_5 = 0.75$), while firms that were not ISO 9000-certified have a reduced probability of JIT adoption due to Chinese competition. While it is true that relatively productive firms are more likely to adopt ISO 9000 certification, our results are useful in that they continue to unbundle what firm actually do to become more productive.

[15]These variables $g_{i(j)}$ are coded into a 0/1 variable relative to the median of the firm's CMAP-3 industry, in analogy to the productivity variable.

The following columns (3) and (4) present results on the importance of certain equipment, in this case industrial robots, for the adoption of Job Rotation techniques. The interaction of competition with the share of robots in total equipment (i.e., β_5) is about 1.6 for both the OLS and IV specification, marginally significant (p-value of 0.16) in the case of the IV. As in Table 4 above, relatively productive firms respond to import competition on average with adoption Job Rotation techniques. The present results indicate that this is reinforced if a firm has relatively large share of robots in their stock of equipment. Moreover, a relatively high share of robots by itself is sufficient to adopt Job Rotation, independent of productivity, according to the point estimates.[16] This is different from worker training, see columns (5) and (6). While generally worker training makes it more likely that firms respond to import competition with rotating jobs (marginally significant in the IV case), it takes both relatively high productivity *and* worker training for firms to actually increase their rate of innovation relative to prior to the arrival of new competition.

The results on sources of technology acquisition are shown in columns (7) and (8) of Table 8. We see that firms that typically acquire their new technology through arm's length purchases tend to innovate more in response to import competition from China ($\beta_5 = 2.8$ in column (8)). One reason for that may be that these firms have learned to evaluate technology by themselves, or they are also faster and more flexibly responding to changes in market conditions. We do not find similar results for the other modes of technology sourcing, in particular, when firms obtain technology typically from their headquarter they tend to innovate less in response to import competition.

Table 9 shows analogous results for two other firm characteristics, profitability and main origin of equipment purchases. In the first two columns, the coefficient β_5 is negative (-1.4 in the IV specification (2)), indicating that firms that are highly profitable before the competition shock hits are less likely to adopt Total Quality Management than less profitable firms. This finding is in line with the idea that these firms find it less necessary than low-margin firms to

[16] We find similar results for the manual equipment (not reported), but not for automatic or computerized equipment.

innovate.[17] Finally, we consider the firms' main country for equipment purchases. The estimates indicate that firms that buy mostly domestic equipment reduce innovation when new import competition appears (β_5 is about -2 in column (4) of Table 9). Note that the productivity of the firm is not a significant predictor of Statistical Control techniques, the particular form of innovation we consider here, neither by itself nor in the interaction with competition. In contrast, the equipment purchase decisions of firms–from abroad or not–are a good predictor of whether firms will innovate in the face of import competition.

Instead of analyzing firm characteristics in 1998, we now turn to changes that firms implement at the same time that they make innovation decisions in the face of import competition.

4.2.3 Firm Strategies that are Complementary to Innovation

We have found above that initially strong performing firms tend to innovate more while weak performers tend to innovate less when hit by the China competition shock. In this section, we investigate whether firms take certain actions that might be complementary to their innovation choices. One possibility is that the Mexican firms that innovate under competitive pressure can do so because they are also the ones that experience an increase in market size relative to other Mexican firms, even though Chinese firms gain market share in Mexico in general. This would be a Schumpeterian mechanism, broadly consistent with recent work emphasizing that firms that experience an increase in market size may simultaneously innovate their technology (Yeaple 2005).

If this were the case, we would expect that Mexican firms with high levels of productivity in 1998, which are the firms that innovate in the face of competition from China, are experiencing on average higher sales growth between 1998 and 2004 than Mexican firms with low levels of productivity in 1998. As shown in Figure 4, however, there is no strong relationship between productivity in 1998 and subsequent sales growth in our sample of Mexican firms; if

[17] At the same time, high profitability generally raises the probability of TQM adoption (coefficient not shown), which gives some support to the liquidity explanantion mentioned above.

anything, the relationship is negative, not positive. It is therefore not the case that differences in innovation behavior are driven by contemporaneous differences in sales.

In the following we extend this analysis to a regression framework and consider additional factors, see Table 10, where Quality Control, as the specific form of innovation we consider, is the dependent variable. Column (1) confirms the message of Figure 4. It shows that even though sales growth in general raises the probability of innovation, in the face of Chinese import competition firms that experience lower sales growth actually innovate more than firms that have higher sales growth (coefficient of -0.81 on sales growth x $\Delta comp_j$). In contrast, firms that increase their imports from China (column (2)) and raise the skill level of their labor force adopt at a higher rate Quality Control techniques than firms that do not do so. This provides initial evidence on firm strategies that are complementary to innovation. Moreover, it is consistent with the role of skill and intermediate imports that we have found in terms of 1998 differences across firms above.

Finally, table eight considers maquiladora plant by introducing an additional interaction to table 5. The interaction of competition with a maquiladora indicator is negative whenever it is significantly different from zero, which counterbalances the positive effect from competition alone. This suggests that maquiladora plants experience smaller marginal effects from competition on innovation, and may highlight that these plants have more experience with a high competition market.

To test the robustness of our competition measure, we re-estimate the results from table 7 with different measures for Chinese competition, and graph coefficients and 90 percent confidence intervals for each. The bars in (a) show our preferred estimate, using the difference of import shares as measure of Chinese competition in the US. Again we find that the marginal response of competition from China is positive for large plants, and negative for small plants. In (b) we replace this measure wed and (d) we repeat the exercise with Chinese imports in Mexico, measured as difference and level respectively. Confidence intervals are wider, and thus significance reduced, but the effect remains largely the same. Finally in (e) and (f) we replace the competition measure with a dummy variable that indicates if the difference of import shares was above or below median competition. Again we find a similar interpretation.

To summarize, from our analysis so far it appears that in the face of new import competition, the differences across firms in terms of their innovative behavior–their forward looking activity–are magnified relative to differences across firms in terms of current sales.

We now turn to some concluding discussion.

5 Conclusions

The Schumpeterian hypothesis that monopolists have a greater incentive to innovate than firms facing tough competition has been revisited by new theory and empirical results finding that more competition may on balance actually increase the rate of innovation. In our analysis of the impact of China's emergence as a force in international trade, we find that the rate of innovation of Mexican plants seems on average unaffected. This may be specific to the shock we are analyzing, which is extraordinary in many respects. At the same time, there is strong evidence that firms with higher labor productivity tend to innovate more than less productive firms in the face of new competition.

For this investigation, we rely on data from surveys on Mexican plants, that allow us to distinguish various specific measures of innovation, such as the introduction of Just in Time management system, job rotation schemes, quality controls, continuous controls and production re-organizations. We find for all these measures that more productive plants are more likely to introduce them as a response to the unilateral competition from China than less productive plants. This difference is strongest for Just in Time. Import competition is thus a force that sharpens the difference between strong-performing and weak-performing firms, a result that is in line with the more qualitative body of research on countries' foreign trade strategies that has been accumulated since World War II.

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	Percent of firms with innovation in 1998	Nr. of firms with innovation in 1998	Percent of firms that adopt innovation between 2000-04	Nr. of firms that adopt innovation between 2000-04
Just in Time	15.4	334	13.7	251
Quality Control	33.5	726	24.7	356
Re-Organization	40	867	26	338
Continuous Control	49.8	1079	27.2	296
Job Rotation	24.5	531	18.2	298

Table 1: Innovation frequency in 1998 and innovation adoption from 2000 to 2004. The total number of firms is 2167.

	Period	Mean	Median	Std Dev
Total Sales	1998	312 k	85 k	1,463 k
	2004	541 k	144 k	2,316 k
Employment	1998	377	228	583 k
	2004	341	210	491 k
Labor training	1998	0.833	1	0.373
	2004	0.719	1	0.449
R & D (%)	1998	0.09	0	3
	2004	1.68	0	34.9
Foreign Ownership	1998	16.3	0	35.41
	2004	16.8	0	35.41
Exporter Status	1998	0.61	1	0.488
	2004	0.579	1	0.494
Intermediates from Asia	1998	0.025	0	0.157
Intermediates from China	1998	0.691	0	4.69

Table 2: Labor training is a dummy variable that indicates the presence of any labor training efforts of firms, R&D measures the share of expenditures for R&D, foreign ownership measures the share of capital from outside Mexico, exporter status is a dummy variable equal to one for exporters, intermediates from Asia indicates by firms if Asia was origin of any intermediates, intermediates from China reports the percent of intermediate imports from China.

	(1) Just in time	(2) Quality control	(3) Total control	(4) Re-ordering	(5) Job rotation	(6) Statistical control
OLS - competition in Mexico						
D comp Mex	-0.029	-0.346**	-0.317	-0.440**	-0.059	-0.147
	(0.166)	(0.138)	(0.282)	(0.214)	(0.138)	(0.226)
Distance to US	-0.016	-0.047	0.008	0.006	-0.012	-0.030
	(0.022)	(0.034)	(0.038)	(0.033)	(0.025)	(0.033)
Mexico city	-0.026	-0.053	0.011	-0.008	-0.027	-0.035
	(0.023)	(0.035)	(0.041)	(0.031)	(0.032)	(0.029)
Age < 5	0.052	-0.035	0.003	-0.023	0.003	-0.006
	(0.035)	(0.050)	(0.060)	(0.043)	(0.041)	(0.048)
Age < 10	-0.010	-0.015	-0.062	-0.005	-0.040	-0.063*
	(0.024)	(0.039)	(0.044)	(0.041)	(0.032)	(0.036)
OLS - competition in the US						
D comp US	-0.202	-0.021	-0.067	-0.312	0.075	0.070
	(0.146)	(0.195)	(0.225)	(0.233)	(0.175)	(0.202)
OLS - competition in the EU						
D comp EU	-0.673***	-0.658*	-0.665**	-1.292***	-0.075	-0.434
	(0.232)	(0.366)	(0.321)	(0.409)	(0.351)	(0.355)
IV - instrument: US						
D comp Mex	-0.792	-0.078	-0.244	-1.031	0.257	0.216
	(0.584)	(0.712)	(0.829)	(0.731)	(0.609)	(0.644)
IV - instrument: EU						
D comp Mex	-0.623**	-0.592	-0.695**	-1.163**	-0.068	-0.326
	(0.292)	(0.371)	(0.336)	(0.462)	(0.322)	(0.305)
Observations	1602	1250	950	1136	1427	1064

Table 3: Control variables (only reported in the first panel) are distance to the US, Mexico City control, Age<5 control, age<10 control, two digit industry fixed effects. They are used in all panels. Robust standard errors clustered by 2 digit industry in parentheses. First stage F-statistics: Instrument *D comp Mex* with *D comp US*: 18.9; with *D comp EU*: 49.4.

	(1) Just in time	(2) Quality control	(3) Total control	(4) Re-ordering	(5) Job rotation	(6) Statistical control
OLS						
D comp EU	-1.024***	-0.885***	-0.764	-1.831***	-0.701**	-0.444
	(0.251)	(0.340)	(0.492)	(0.349)	(0.300)	(0.345)
D comp EU x	0.952	0.590	0.346	1.577**	1.535*	-0.022
productivity	(0.621)	(0.613)	(1.070)	(0.625)	(0.783)	(0.559)
Initial	-0.015	-0.017	0.021	-0.025	-0.054**	-0.017
productivity	(0.023)	(0.031)	(0.042)	(0.028)	(0.026)	(0.031)
Observations	1602	1250	950	1136	1427	1064
IV: Instrument: D comp EU and D comp EU x productivity						
D comp Mex	-0.953***	-0.777**	-0.832	-1.825***	-0.675**	-0.312
	(0.280)	(0.354)	(0.517)	(0.476)	(0.303)	(0.277)
D comp Mex x	0.882	0.483	0.406	1.716**	1.513**	-0.077
productivity	(0.549)	(0.601)	(1.080)	(0.708)	(0.734)	(0.471)
Initial	-0.021	-0.019	0.019	-0.043	-0.067**	-0.014
productivity	(0.027)	(0.035)	(0.047)	(0.034)	(0.031)	(0.034)
Observations	1602	1250	950	1136	1427	1064

Table 4: Control variables (not reported): Distance to the US, log initial labor productivity, Mexico City control, Age<5 control, age<10 control, two digit industry fixed effects. Robust standard errors clustered by 2 digit industry in parentheses. First stage F-statistics: Instrument *D comp Mex* and *D comp Mex x productivity* with *D comp EU* and *D comp EU x productivity*: 61.7 and 44.8, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Just in time		Quality control		Continuous control		Re-Organization		Job rotation	
Competition	-0.541***	-0.532**	-0.314	-0.390	-0.473	-0.575*	-0.694**	-0.749***	-0.380*	-0.473**
	(0.179)	(0.216)	(0.268)	(0.254)	(0.300)	(0.339)	(0.270)	(0.256)	(0.212)	(0.218)
Competition x Labor	0.667**	0.697**	0.595*	0.656*	0.854*	0.889*	0.742**	0.760**	0.859***	0.838***
prod in 1998	(0.265)	(0.284)	(0.351)	(0.354)	(0.481)	(0.502)	(0.346)	(0.363)	(0.290)	(0.300)
Labor prod. In 1998	-0.038	-0.043	-0.041	-0.047	-0.027	-0.034	-0.041	-0.053*	-0.078***	-0.079***
	(0.027)	(0.026)	(0.036)	(0.035)	(0.047)	(0.046)	(0.031)	(0.030)	(0.029)	(0.030)
Distance to US	-0.018	-0.022	-0.052	-0.049	0.007	0.008	0.004	-0.001	-0.020	-0.017
	(0.022)	(0.020)	(0.034)	(0.031)	(0.038)	(0.037)	(0.032)	(0.032)	(0.025)	(0.025)
Mexico City	-0.022	-0.021	-0.055	-0.059*	0.015	0.021	-0.003	-0.010	-0.027	-0.031
	(0.022)	(0.023)	(0.036)	(0.036)	(0.042)	(0.042)	(0.031)	(0.030)	(0.032)	(0.029)
Age < 5 years	0.049	0.042	-0.036	-0.046	-0.003	-0.006	-0.028	-0.035	0.003	-0.002
	(0.035)	(0.034)	(0.049)	(0.050)	(0.061)	(0.059)	(0.044)	(0.043)	(0.041)	(0.039)
Age < 10 years	-0.010	-0.010	-0.013	-0.012	-0.059	-0.066	-0.002	-0.007	-0.036	-0.037
	(0.024)	(0.024)	(0.039)	(0.038)	(0.044)	(0.043)	(0.041)	(0.042)	(0.032)	(0.032)
Observations	1604	1604	1250	1250	951	951	1136	1136	1429	1429
Method	OLS	Probit	OLS	Probit	OLS	Probit	OLS	Probit	OLS	Probit

Table 5: Industry fixed effects at the CMAP 2 digit level included. Robust standard errors clustered at the CMAP 6 digit level. For the probit estimations the table reports marginal effects.

	(1) Just in time	(2) Just in time	(3) Quality control	(4) Quality control	(5) Total control	(6) Total control	(7) Re-ordering	(8) Re-ordering	(9) Job rotation	(10) Job rotation	(11) Statistical control	(12) Statistical control
OLS												
Competition	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low
D comp Mex	0.241	-0.357	-0.211	-0.449**	0.036	-0.722**	-0.233	-0.753***	-0.032	-0.059	-0.218	-0.149
	(0.247)	(0.232)	(0.173)	(0.224)	(0.480)	(0.360)	(0.232)	(0.285)	(0.250)	(0.224)	(0.275)	(0.261)
Observations	838	764	642	608	472	478	604	532	775	652	541	523
OLS												
D comp US	0.278	-0.657***	0.352	-0.451	0.331	-0.499	0.156	-0.822***	0.485**	-0.322	0.421	-0.367
	(0.221)	(0.209)	(0.281)	(0.304)	(0.359)	(0.312)	(0.274)	(0.270)	(0.238)	(0.244)	(0.306)	(0.274)
Observations	838	766	642	608	472	479	604	532	775	654	541	524
OLS												
D comp EU	0.080	-1.175***	-0.103	-1.043***	-0.482	-0.919*	-0.301	-1.881***	0.694	-0.672**	-0.280	-0.635*
	(0.607)	(0.345)	(0.645)	(0.373)	(0.796)	(0.528)	(0.665)	(0.370)	(0.770)	(0.339)	(0.584)	(0.354)
Observations	838	764	642	608	472	478	604	532	775	652	541	523
IV - instrument US												
D comp Mex	1.105	-2.581**	1.268	-1.734	1.343	-1.756	0.515	-2.696***	1.716*	-1.064	1.369	-1.163
	(0.923)	(1.284)	(1.135)	(1.197)	(1.570)	(1.204)	(0.918)	(0.993)	(0.997)	(0.900)	(1.155)	(0.927)
Observations	838	764	642	608	472	478	604	532	775	652	541	523
IV - instrument EU												
D comp Mex	0.072	-1.171***	-0.093	-0.988**	-0.442	-1.149*	-0.244	-1.809***	0.636	-0.591*	-0.218	-0.491
	(0.540)	(0.371)	(0.587)	(0.458)	(0.744)	(0.632)	(0.531)	(0.520)	(0.670)	(0.320)	(0.471)	(0.332)
Observations	838	764	642	608	472	478	604	532	775	652	541	523

Table 6: Control variables (not reported): Distance to the US, Mexico City control, Age<5 control, age<10 control, two digit industry fixed effects. Robust standard errors clustered by 2 digit industry in parentheses.

	Mean Competion	Observed adoption	% explained by by comp	Comp Coeff High LP	Observed adoption for High LP	Fraction explained by comp for High LP
Job Rotation	0.38	0.18	0.13	0.49	0.17	0.18
Just in Time	0.16	0.14	0.07	0.28	0.14	0.12
Qual. Control	0.25	0.25	0.06	0.35	0.24	0.09
Contin. Control	0.23	0.27	0.05	0.33	0.29	0.07
Re-Organization	0.03	0.26	0.01	0.16	0.26	0.04

Table 7: Import competition and innovation: Some magnitudes.

	(1) Just in Time OLS	(2) Just in Time IV	(3) Job Rotation OLS	(4) Job Rotation IV	(5) Re-Config OLS	(6) Re-Config IV	(7) Re-Config OLS	(8) Re-Config IV
Interaction	ISO 9000		Robots Share		Worker Training		Arm's length tech acq	
D comp	-1.152***	-1.044***	-0.832***	-0.771**	-2.516***	-2.429***	-2.116***	-2.101***
	(0)	(0)	(0.006)	(0.019)	(0)	(0)	(0)	(0)
D comp x	0.751	0.625	1.480*	1.427**	1.738***	1.974**	1.684***	1.883**
productivity	(0.174)	(0.236)	(0.058)	(0.05)	(0.005)	(0.017)	(0.007)	(0.012)
Initial productivity	-0.017	-0.019	-0.054**	-0.066**	-0.027	-0.05	-0.027	-0.048
	(0.446)	(0.455)	(0.037)	(0.036)	(0.309)	(0.165)	(0.331)	(0.175)
Competition x	2.013*	1.800**	1.597*	1.554	1.474**	1.367	2.484**	2.778*
variable	(0.063)	(0.041)	(0.071)	(0.156)	(0.012)	(0.14)	(0.023)	(0.071)
Variable	0.012	-0.01	-0.007	1.554	-0.018	-0.034	-0.02	-0.056
	(0.642)	(0.766)	(0.87)	(0.156)	(0.581)	(0.395)	(0.699)	(0.367)
Observations	1602	1602	1402	1402	1136	1136	1136	1136

Table 8: Control variables (not reported): Distance to the US, Mexico City control, Age<5 control, age<10 control, two digit industry fixed effects. Competition denotes competition as measured in the EU in the case of OLS, and competition in Mexico instrumented in the EU in the case of IV. P values obtained from robust standard errors clustered by 2 digit industry in parentheses. Variable reports a dummy variable indicating if the variable given on column heads is above or below its mean. Instruments for competition, competition times size and competition times var are the same three measures with competition to EU instead of Mexico.

	(1)	(2)	(3)	(4)
	Total Control	Total Control	Statistical Control	Statistical Control
	OLS	IV	OLS	IV
Interaction	High profitability		Domestic source for machinery	
D comp	0.056	0.01	0.016	0.068
	(0.93)	(0.987)	(0.97)	(0.8451)
D comp x	0.486	0.585	-0.318	-0.358
productivity	(0.639)	(0.597)	(0.572)	(0.476)
Initial productivity	0.01	0.007	-0.015	-0.011
	(0.8)	(0.856)	(0.647)	(0.754)
Competition x	-1.306**	-1.429**	-2.301***	-1.953***
variable	(0.05)	(0.039)	(0.003)	(0.01)
Variable	0.075*	0.087*	0.014	0.028
	(0.064)	(0.052)	(0.73)	(0.527)
Observations	1136	1136	1136	1136

Table 9: Control variables (not reported): Distance to the US, Mexico City control, Age<5 control, age<10 control, two digit industry fixed effects. Competition denotes competition as measured in the EU in the case of OLS, and competition in Mexico instrumented in the EU in the case of IV. P values obtained from robust standard errors clustered by 2 digit industry in parentheses. Variable reports a dummy variable indicating if the variable given on column heads is above or below its mean. Instruments for competition, competition times size and competition times var are the same three measures with competition to EU instead of Mexico.

	Sales growth	Import Growth from China	Skill growth
Competition	0.137	-0.489	-0.713
	(0.689)	(0.071)	(0.013)
Comp x Labor Productivity	0.56	0.636	0.649
	(0.105)	(0.077)	(0.056)
Comp x Sales Growth	-0.812		
	(0.006)		
Sales Growth	0.058		
	(0.046)		
Comp x Imports from China		1.286	
		(0.039)	
Imports from China		-0.057	
		(0.386)	
Comp x Skill Lab Share Growth			0.702
			(0.045)
Skill Lab Share Growth			-0.097
			(0.002)
R2	0.021	0.021	0.023

Table 10: Number of observations: 1,250. Specifications also include constant, labor productivity, Mexico City indicator, distance to US border, age and two-digit industry dummies. P-values based on robust and clustered standard errors in parentheses. The outcome variable is quality control. Number of observations: 1,429. Specifications also include constant and Mexico City indicator, distance to US border, age and two-digit industry dummies. P-values based on robust and clustered standard errors in parentheses.

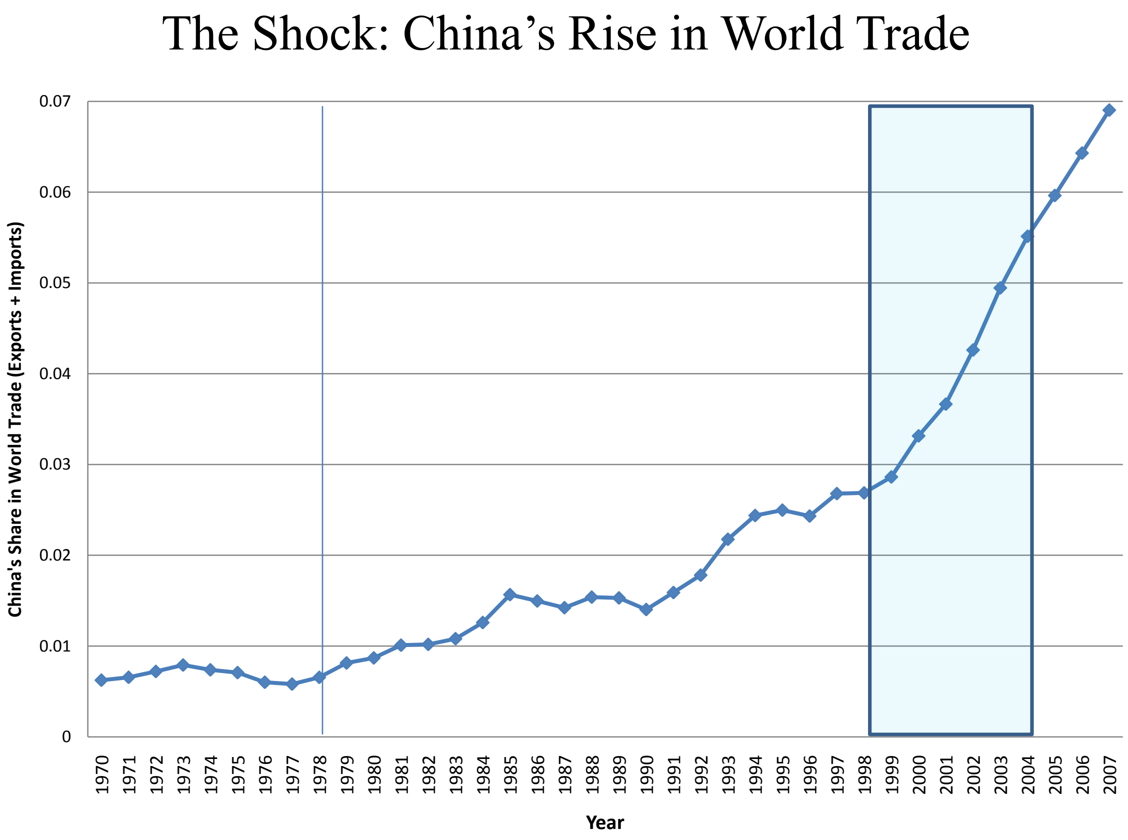

Figure 1: Chinese exports over time.

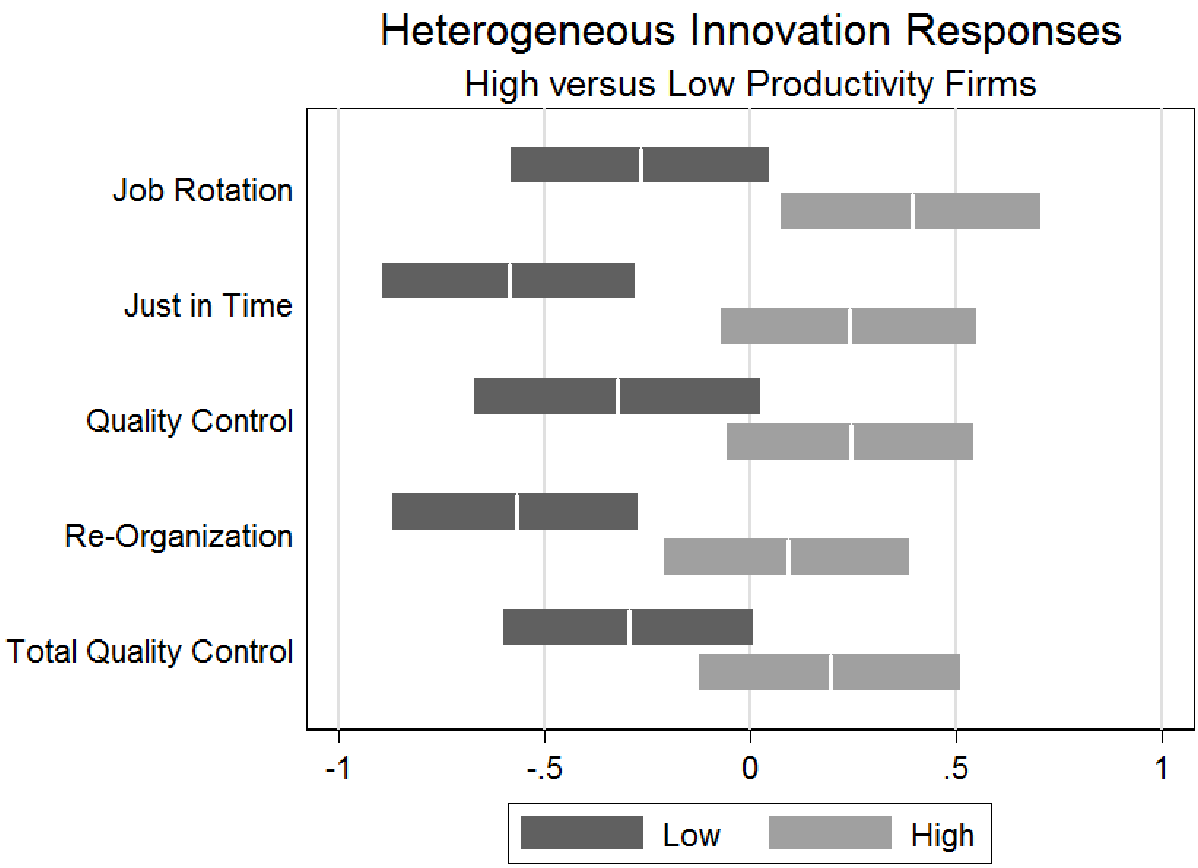

Figure 2: Productivity measured by labor productivity above (high) or below (low) sample mean. Bars indicate marginal mean effects and 90 percent confidence intervals for the competition coefficient.

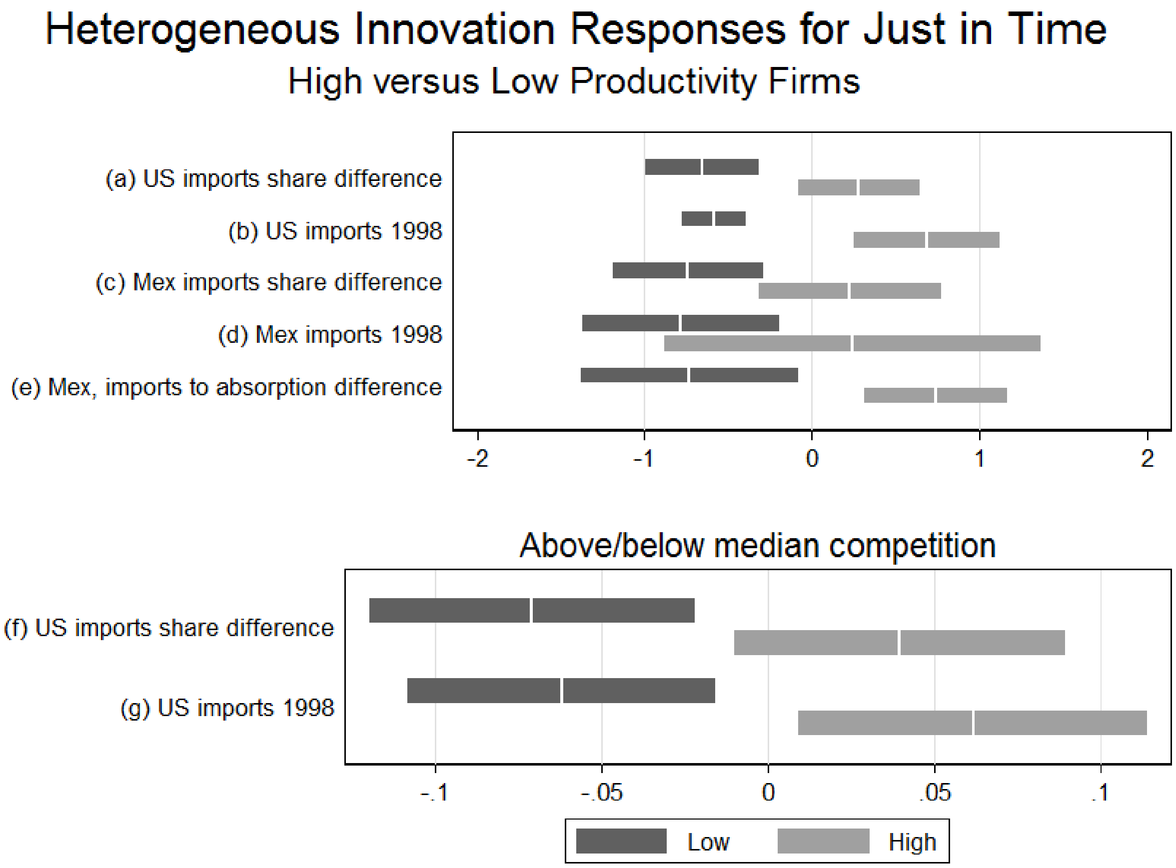

Figure 3: Productivity measured by labor productivity above (high) or below (low) mean. Bars indicate marginal mean effects and 90 percent confidence intervals for the competition coefficient.

Figure 4: Labor productivity of plants and sales growth.