WARWICK
THE UNIVERSITY OF WARWICK

Feb 2019 No.404

Innovation and the Patterns of Trade: A Firm-Level Analysis

Ana Maria Santacreu and Liliana Varela

WORKING PAPER SERIES

Centre for Competitive Advantage in the Global Economy

Department of Economics

CAGE
Competitive Advantage in the Global Economy

E·S·R·C
ECONOMIC & SOCIAL RESEARCH COUNCIL

Innovation and the Patterns of Trade: A Firm-Level Analysis

Ana Maria Santacreu   Liliana Varela*

February 2019

Abstract

This paper studies the impact of increased import penetration on a country's long-term patterns of trade. It shows that foreign competition induces firms to increase their R&D efforts in order to differentiate their products and escape competition. Quality improvements translate into increases in firms' exports. This effect, however, is heterogeneous across sectors and is driven by sectors' in which the country has a comparative advantage. On the aggregate, the impact of import competition on innovation and a country's patterns of trade depends crucially on the distribution of sectoral comparative advantage. We provide evidence of this mechanism using firm-level data on trade and innovation for France and import competition driven by China's WTO entry.

Keywords: quality upgrading, import competition, patterns of trade, comparative advantage.
JEL: F12, F14, O30, O41.

*Santacreu, Federal Reserve Bank of St. Louis, am.santacreu@gmail.com. Varela, University of Warwick, CEPR and CAGE, L.Varela@warwick.ac.uk. Varela acknowledges funding from the Centre for Competitive Advantage in the Global Economy from the University of Warwick. The views expressed herein are those of the author and do not necessarily represent those of the Federal Reserve System, the Board of Governors, or the Regional Federal Reserve Banks.

1 Introduction

What is the impact of import competition on a country's patterns of trade? The rise of China as a major player in global trade has been at the center of academic and policy-makers debates over the last decade. Much has been discussed about the impact of import penetration on firms' performance and incentives to invest in technology. Yet there is so far little understanding about its the sectoral and aggregate impacts. Does import penetration affect sectors' comparative advantage? Does it affect a country's patterns of trade? If so, how? This paper takes on this challenge and studies these questions empirically.

We uncover three new stylized facts regarding the impact of import competition on innovation and the patterns of trade. First, we show that the impact of import penetration depends crucially on sectors' initial comparative advantage. Firms in already competitive sectors succeed in escaping competition by increasing the quality and number of products exported. Higher R&D efforts and product innovation allow them to increase their exports and competitiveness in the global economy. We refer to this as the pro-competitive effect of import penetration. Second, we demonstrate that, dynamically, pro-competitive effects translate into an improvement of the comparative advantage of these sectors. On the contrary, sectors with an initial comparative disadvantage do not report pro-competitive effects and lower their comparative advantage. Finally, on the aggregate, the impact of import penetration on a country's exports and patterns of trade depends on the initial distribution of sectoral comparative advantage. We test these effects by using firm-level data on innovation and trade for France over three decades (1985-2016) and exploit the trade shock produced by the joining of China to the World Trade Organization (WTO) in 2000 as an exogenous source of time variation. This extensive dataset is ideal to study this question, as its long panel allows us to track the evolution of firms' R&D and trade activities over a long period and, hence, to study the dynamic implications of import penetration on the long term.

To assess the impact of import penetration on firms' innovation activities and a country's patterns of trade, we merge three datasets: customs data that reports all exports and imports in France, balance sheet data reported to tax authorities and R&D and innovation surveys. The coverage of the dataset is unique as it provides detailed information on R&D efforts and export behavior over three decades and constitutes an advance over previous studies that focus on broad measures of innovation, such as patenting, TFP or R&D expenditure. Our data allows us to construct firm-level measures of R&D efforts and export performance, such as the share of researchers employed in R&D and the number and quality of products exported.

To identify the impact of import penetration on innovation and the patterns of trade, we exploit the trade shock produced by the joining of China to the WTO in 2000 and use changes in Chinese imports at four-digit industries as proxy for import penetration.[1] To control for unobserved technology shocks in France that could be correlated with import penetration, we follow Autor, Dorn, Hanson, Pisano, and Shu (2016) and instrument Chinese imports into France with import

[1]See Autor, Dorn, Hanson, and Song (2014); Autor, Dorn, Hanson, Pisano, and Shu (2016); Bloom, Draca, and Reenen (2016); Medina (2018) and Hombert and Matray (2018) for similar identification strategy.

penetration in other high-developed countries. Since market size effects could encourage French firms' R&D efforts and exports, we follow Aghion, Bergeaud, Lequien, and Melitz (2018) and control for the increase in market size following the Chinese trade openness.

We start by documenting that the Chinese trade shock had a large impact on France's imports. Between 2000 and 2016, the value of Chinese imports surged by four-fold, the number of firms importing from China expanded by five-fold, and the number of Chinese products doubled. By 2016, half of the products imported by France were directly coming from China. Parallel to this increase, there is an expansion in the share of researchers and employment in R&D during this period. Critically, the increase in R&D efforts is accounted for by sectors that faced higher import penetration from China.

To test whether this correlation is the result of pro-competitive forces rather than a mere coincidence, we estimate econometrically the impact of import penetration at four-digit NACE industries on firms' R&D efforts and export behavior. First, we show that, while firms in sectors more exposed to Chinese import penetration were not differentially investing in technology prior to the shock, they substantially increased their innovation efforts upon it. In particular, our instrumental variable (IV) estimates indicate that a 10 percentage point increase in import penetration raises the share of R&D employment by 11.3%, the share of researchers by 8.8% and the probability of conducting product innovation by 6.5%. Second, we demonstrate that the expansion in R&D efforts translates in a better export performance. Our estimated IV coefficients indicate that a 10% increase in import penetration associates with 13.6% expansion in the number of product exported, a 8.25% increase in the quality of exported products and a 16% rise in the value of exports. As a robustness, we show that higher R&D efforts are in line with increases in labor productivity, R&D expenses and probability of patenting.

These effects are, however, heterogenous across sectors. We construct a measure of revealed comparative advantage for each four-digit NACE sector prior to the China shock and show that these effects are driven by sectors in which France had a comparative advantage to begin with. In these sectors, firms differentially increase their investment in technology and the quality and number of products exported.

These results indicate that firms escape competition by investing in technology to differentiate their products and export more sophisticated goods. Yet not all firms can afford this strategy. Only already competitive firms in the world economy can escape competition by differentiating their products. Firms in sectors with comparative disadvantage lose market share.

Finally, we assess the long-term implications of pro-competitive forces and study the evolution of sectors' comparative advantage. We first show that sectors with higher import penetration increased their revealed comparative advantage after the China shock. We next document that this expansion is driven by sectors in which France that had a comparative advantage to begin with. On the contrary, sectors having a comparative disadvantage prior to the shock and facing high import competition lower their competitiveness in the global economy. These results suggest that the aggregate consequences of import competition on a country's patterns of trade depend crucially on the distribution of sectoral comparative advantage prior to the shock.

Our paper contributes to a long literature studying the impact of trade liberalizations on firms' investment in technology and export patterns (Bustos 2011; Lileeva and Trefler 2010; Coelli, Moxnes, and Ulltveit-Moe 2016; Bloom, Draca, and Reenen 2016; Bloom, Romer, Terry, and Van Rennen 2018; Atkeson and Burstein 2010 and Akcigit, Ates, and Impullitti 2018, among others). Our paper differs from Bustos (2011) and Lileeva and Trefler (2010) in that – in our paper – firms' incentives to invest in technology arise from deeper import competition, instead of increases in the market size. In this sense, our paper is closest to Bloom, Romer, Terry, and Van Rennen (2018) and Akcigit, Ates, and Impullitti (2018) who highlight the pro-competitive forces of import penetration on firms' innovation efforts and exports.[2] We depart from them in that we identify empirically the impact of import competition and assess its heterogeneous effects across sectors and its long-term effect on a country's pattern of trade.

Our paper is also related to a strand of literature that studies the impact of import competition on quality upgrading, as in Verhoogen (2008); Khandelwal (2010); Amiti and Khandelwal (2013); Fieler, Eslava, and Xu (2018); Bas and Strauss-Kahn (2015); Medina (2018) and Hombert and Matray (2018). Our paper is close to Medina (2018) in that we study the impact of Chinese penetration on quality upgrading. We depart from her in that we show that the pro-competitive effect of import penetration depends crucially on sectors' initial comparative advantage and that its aggregate effect depends on the initial distribution of sectors' competitiveness in the global economy. Our paper relates to Khandelwal (2010) and Amiti and Khandelwal (2013) in that we measure the changes in export quality following trade shocks. Similarly to Hombert and Matray (2018); Bloom, Draca, and Reenen (2016); and Autor, Dorn, Hanson, Pisano, and Shu (2016), we study the impact of the Chinese trade liberalization following the joining to the WTO.[3]

Lastly, this paper also relates to the literature on firms' dynamics and exports that studies how firms' investment in technology affect their export behavior, as in Atkeson and Burstein (2010); Aw, Roberts, and Xu (2011); Sampson (2016) and Akcigit, Ates, and Impullitti (2018). We are also close to Somale (2014), and Cai, Li, and Santacreu (2017) who build quantitative frameworks to study how innovation efforts affect country's comparative advantage. We depart from them in that we highlight the escape competition effect and present firm-level evidence for this mechanism across sectors.

The remainder of the paper is organized as follows. Section 2 describes the different datasets. Section 3 introduces our motivating facts. Section 4 presents the empirical strategy and results. Section 5 concludes.

[2]This paper is also closely related to the industrial organization literature that highlights that firms invest in technology in order to escape competition. See Grossman and Helpman (1991), Aghion and Howitt (1992), Aghion, Bloom, Blundell, Griffith, and Howitt (2005) and Holmes and Schmitz (2010), among others.

[3]There is also a literature that studies the product mix of exporters, see Bernard, Redding, and Schott (2010); Mayer, Melitz, and Ottaviano (2014) and Mayer, Melitz, and Ottaviano (2016), among others.

2 Data

We employ firm-level data on trade and R&D efforts from France between 1993 and 2016 to assess the impact of increased import penetration on firms' innovation efforts and export patterns, and use the shock produced by the joining of China to the World Trade Organization in 2000 as a policy experiment.

We merge three datasets on French firms: (i) the Survey on R&D and Innovation Activities produced by the French Ministry of Education, (ii) Customs data on export and imports produced by the French Customs Office, and (iii) Balance sheet data produced by the National Statistical Institute (INSEE). The Survey on R&D and Innovation Activities covers firms located in France that may undertake R&D investment.[4] The survey follows the methodology of the Frascati Manual from the OECD to measure R&D and innovation activities. We employ this data to build two key measures of firms' R&D efforts: the share of R&D employment (employment in R&D over total employment) and the share of researchers (researchers over total employment). These variables are our preferred indicators for R&D efforts, as they reflect the within-firm allocation of labor to innovation activities and measure R&D intensity directly. Furthermore, they are expressed in physical units and, thus, are not affected by changes in prices, as spending measures. They also present advantages over patenting indicators, as patenting requires several years to take place and its practice varies across firms, sectors and time. Yet, for robustness, we also include in our analysis variables as R&D expenditures, a dummy indicating if a firm applied for a patent and labor productivity (sales per worker).[5] Since 1999, the survey also reports information on whether firms conduct product innovation that we use to estimate the probability of undertaking these activities. Additionally, we use employment as an indicator for firms' performance. Since we estimate the impact of Chinese opening to trade within firms over time, we keep firms that have at least five years of consecutive observations. This gives an average of 3,798 firms per year over the sample period.

We proxy firms' export behavior with three indicators: number of exported products, quality of products and value of total exports. We create these variables using French customs for firm-level data. This database reports the value (in euros) of export and imports for each eight-digit product and destination for each firm located in the French metropolitan territory.[6] We employ this data to retrieve the number of products exported as the number of eight-digit sectors and value of exports.

[4]This survey has been conducted since 1980 by the French Ministry of Education, which has built a directory of firms conducting R&D and innovation activities by using historical information from various sources. In 2000, the directory of the survey was 15,300 firms, from which 10,040 were surveyed. The survey is stratified by firms that are questioned every year and a random sample that is renewed yearly. Firms conducting R&D regularly are surveyed every year. Smaller firms are randomized according to the research activity and region. See Appendix A.2 for detailed information about the survey.

[5]The information on patents only starts in 1999. Since many firms do not report patents and the data is scattered, we employ a dummy if the firm reports to have applied to a patent in the year.

[6]Small shipments are excluded from this database. In particular, firms trading less than 150,000 euros within the EU are not required to reports these flows and there is a minimum of 1,000 euros to record trade outside the EU. These exports only eliminate a small proportion of trade. Export and import data are reported in the Combined Nomenclature (CN), which is the EU version of the HS at eight digit level.

To assess whether firms' R&D efforts associate with changes in the quality of the products exported, we follow Khandelwal (2010) and construct an index of export quality at the firm level. We create this measure as the weighted average of the quality in the sector weighted by the firm's export share in that sector and year. More precisely, a firms' export quality is given by:

$$\text{export quality}_{it} = \sum_{j} s_{ijt}\, \lambda_j, \tag{1}$$

where s_{ijt} is the export share of firm i in the four-digit sector j and year t, and λ_j is the quality ladder of the four-digit sector in the United Stated built by Khandelwal (2010) for the pre-WTO period. The use of this quality measure for the United States avoids endogeneity concerns that could arise from French exports being correlated with Chinese imports. Finally, we use French customs data to create a direct measure of import penetration from China into France.

The balance sheet data contains firm-level information on sales, value added, employment and sector of activity, among others. This database is constructed from mandatory reports of French firms to the tax administration. Between 1993 and 2000, it contained approximately two million firms per year, from which approximately 360,000 employed five or more workers. We keep firms with five or more employees and employ this database to compare it with the R&D survey.

Table 1 presents main descriptive statistics for firms in the balance sheet data (column 1) and firms in the R&D survey data (column 2) between 1993 and 1999. Column 2 shows that firms conducting R&D activities were, on average, larger (sales and employment), more productive and export more. Most of these firms were exporters (95%) and their export share was substantially larger than that of the average firm in France.

Table 1: Summary Statistics

	All firms	R&D Survey
	(1)	(2)
Sales*	5,323	135,590
Employment	31	755
Labor productivity*	138	190
Exports*	877	31,849
Share of exporting firms	0.23	0.95
Export share	0.16	0.23
Number of firms	360,506	3,635

Note: *In thousands of Euros. Labor productivity is computed as sales per worker. This table includes firms with at least five employees. Period 1993-1999. Source: FICUS/FARE, Customs Data and R&D Survey.

Table 2 illustrates that firms in the innovation survey allocated – on average – 7% of employment to R&D activities, from which almost half of them were researchers (3% of total firms' employment). Almost 60% of firms were conducting product innovation and their R&D intensity –computed as total R&D expenses over sales– was 4%. Firms undertaking R&D activities were exporting to and importing from a large number of sectors. On average, these firms exported to 27 sectors disaggregated at eight-digit industry-level and were importing from 38 sectors. These firms had an average of six patents per firm.

Table 2: Summary Statistics on Innovation

	Mean	p25	p75
	(1)	(2)	(3)
Share of R&D employment	0.07	0.03	0.23
Share of researchers	0.03	0.01	0.14
Share of firms doing product innovation*	0.59		
Share of firms patenting*	0.26		
R&D intensity	0.04	0.02	0.13
Number of firms	3,635		

Note: This table includes firms with at least five employees. Period 1993-1999. R&D intensity is expenses in R&D over sales. *This data corresponds to the year 1999. Source: Customs Data and R&D Survey.

To estimate the impact of Chinese imports, we create a measure of import penetration as the year change in imports from China at the four-digit NACE industry level, weighted by the share of total world imports in each sector in the initial year (1993), following the "value share" approach of Bernard, Jensen, and Schott (2006) and Bloom, Draca, and Reenen (2016). In particular, the import penetration measure for France – IP_{jt}^{FC} – becomes

$$IP_{jt}^{FC} = \frac{\text{Impo}_{jt}^{FC} - \text{Impo}_{jt-1}^{FC}}{\text{Impo}_{j1993}^{FW}}, \tag{2}$$

where j and t denote four-digit NACE industries and time, Impo_{jt}^{FC} denotes France's imports from China in each sector and year, and Impo_{j1993}^{FW} is total world imports of France in sector j in 1993. Weights are normalized to the the initial year to avoid endogeneity concerns.

Since imports from China could be correlated with industry-level domestic shocks that could affect both France's import demand and R&D and innovative activities, we create a measure for exposure to trade to capture the supply-driven component of Chinese imports. We follow Autor, Dorn, Hanson, Pisano, and Shu (2016) and construct an instrument for trade exposure – IP_{jt}^{OC} – as the yearly change in Chinese imports of other countries in four-digit NACE industries, weighted by the share of total world imports in each sector of these countries in 1993. Our sample of countries includes OCDE countries other than European countries and the U.S., that is, Australia, Canada, Chile, Israel, Japan, Korea, Mexico, New Zealand and Turkey. We exclude European countries and the U.S. to avoid possible endogeneity concerns that could arise from industry-level shocks being correlated across European countries and between France and the U.S. More precisely, our measure for import penetration in other countries is

$$IP_{jt}^{OC} = \frac{\text{Impo}_{jt}^{OC} - \text{Impo}_{jt-1}^{OC}}{\text{Impo}_{j1993}^{OW}}, \tag{3}$$

where $\text{Impo}_{j1993}^{OW} = \sum_i \text{Import}_{j1993}^{iW}$ and i is Australia, Canada, Chile, Israel, Japan, Korea, Mexico, New Zealand and Turkey. We employ UN Comtrade data to measure Chinese imports of other high developed economies. This data reports six-digit product level information on all bilateral exports and imports between country pairs. We aggregate six-digit level data to four-digit NACE industry level using the concordance table produced by the World Integrated Trade Solution from the World Bank, as detailed in Appendix A.2. Real prices are obtained using the Personal Consumption Expenditures of the U.S. from FRED. Table 3 presents the summary statistics of import growth from China of France and other high developed economies from 1993- 2016 and disaggregated by period. It shows that Chinese imports substantially increased after the joining of China to the WTO.

Table 3: Chinese Import Growth of France and High-Income Countries

	Period		
	1993-2016 (1)	1993-1999 (2)	2000-2016 (3)
		IP^{FC}_{jt}	
Mean	0.299	0.097	0.349
Standard deviation	(1.307)	(0.354)	(1.450)
		IP^{OC}_{jt}	
Mean	0.339	0.074	0.404
Standard deviation	(1.718)	(0.213)	(1.913)

Source: in percentage terms. French Customs Data and UN Comtrade data.

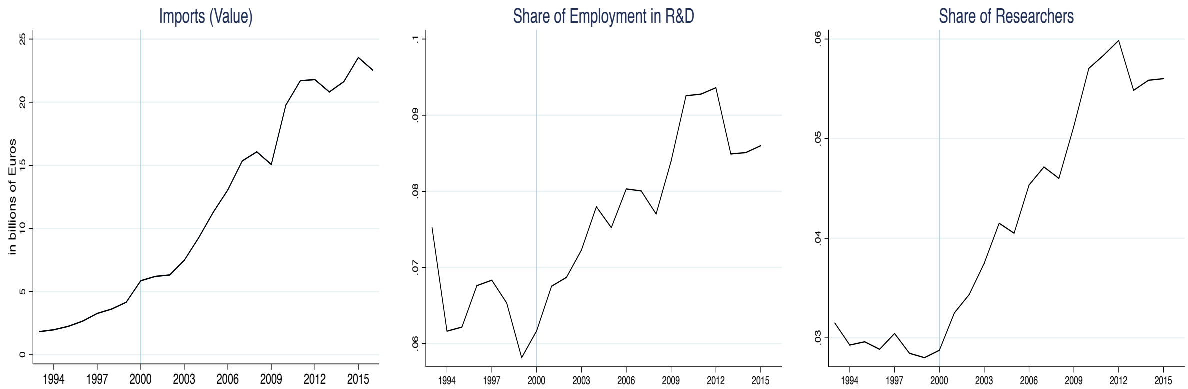
Finally, since the Chinese trade openness increases market size and might have induced firms to increase their exports to that destination and their R&D efforts through increased market size, we need to control for it. With this end, we follow Aghion, Bergeaud, Lequien, and Melitz (2018) and construct a variable with the increase in exports to China at the four-digit NACE industries for fourteen European countries: UK, Germany, Italy, Spain, Portugal, Belgium, Greece, Netherlands, Sweden, Austria, Denmark, Ireland, Luxembourg and Finland, which is EU15 except for France. We exclude France to avoid simultaneity concerns that could arise from R&D activities increasing exports, and add it as a robustness test. We consider European countries as these have similar export patterns than France and assume that R&D activities in France are not correlated with other European countries' exports. Our firm-level regressions control for aggregate shocks for which we employ data on GDP growth and unemployment rate of the EU countries, which was extracted from the World Bank data.

3 Import Penetration and R&D Efforts between 1993 and 2016

Following the joining of China to the WTO, there was an upsurge of Chinese imports into France. The value of imports from China increased by almost four-fold between 2000 and 2016, as shown in the left graph of Figure 1. Table 4 breaks down sample into three periods pre-WTO (i.e. 1993-

1999), post WTO (2000-2008) and post-financial crisis (2009-2016) and reports the acceleration in Chinese import penetration after the joining of China to the WTO. While imports from China were on average 2.8 billions of Euro per year pre-WTO, they had reached 10 billions of Euro yearly in the post-WTO period, and had doubled this number - 20.8 billions of Euros yearly - after the financial crisis (columns 1 and 2).[7][8]

Figure 1: France: Imports from China and R&D Efforts



A first glance at the data suggests that, after 2000, firms in France allocated more resources to R&D. As shown in Figure 1, both the share of R&D employment and the share of researchers substantially expanded. Between pre-WTO and post-financial crisis periods, the share of employment in R&D increased by 50% and the share of researchers doubled (columns 3 and 4 in Table 4). Remarkably, this pattern of growth post-WTO contrasts with the pre-WTO period when these both the employment share in R&D and the share of researchers remained mostly constant.

These figures illustrate a parallel increase in import penetration and higher resources allocated to R&D post-2000. We now go one step further and explore whether import penetration from China correlates with changes in the allocation of employment in R&D across sectors. To do this, we split sectors according to whether they experience high or low import penetration after the joining of China to the WTO and follow their evolution of employment allocated to R&D.[9] Figure 2 reports the evolution of the share of employment in R&D and share of researchers in the

[7]This expansion is parallel to a substantial increase in the number of firms importing products from China, which grew from 8,000 to 30,000 between 2000 and 2016 (Table A1 and Figure A1 in Appendix A.2). There has been also a significant increase in the number of products (eight-digit industries) that import from China. The number of products grew from an average of 3,000 products per year between 1993 and 1999, to 4,551 between 2000 and 2008, and an average of 5,458 between 2009 and 2016. The share of Chinese imported products on total world imports doubled from 29% to 59% between 1993 and 2016. (Table A1 in Appendix A.2). For robustness, we present in Figure A3 the evolution of total and manufacturing imports using UN Comtrade data.

[8]This expansion is parallel to an increase in French exports to China. Figure A2 and Table A2 in Appendix A.2 show that total exports increased from 3 billion of Euros to 16 billion of Euros between 2000 and 2016. The number of firms exporting to France rose by three-fold from 4,000 to 12,000 between 2000 and 2016.

[9]More precisely, we use our measure of import penetration from equation (2) and compute the median import penetration of the economy between 2000 and 2016. We then check whether each four-digit NACE sector is above or below this value, and split sectors in these two groups. The evolution presented in Figure 2 is the evolution of the median sector that is above or below the import penetration in the economy.

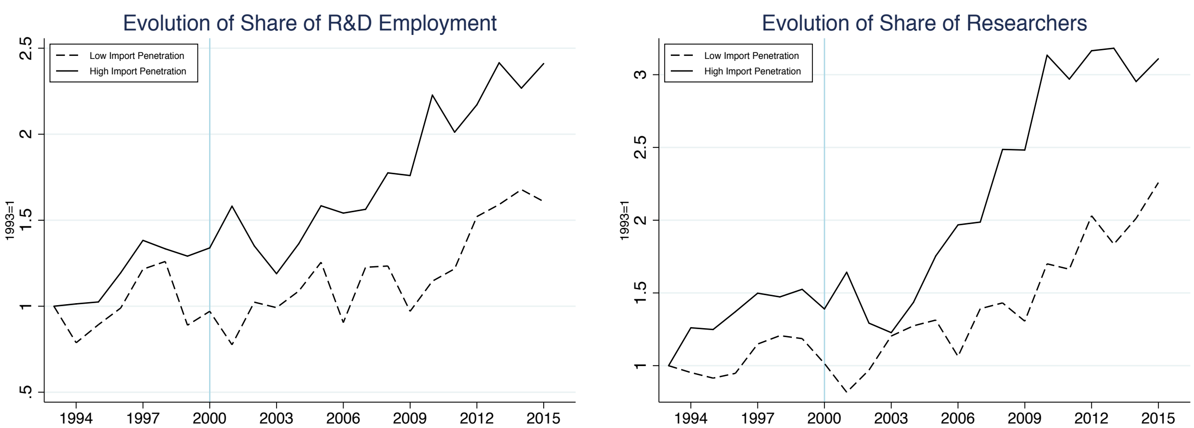
Table 4: France: Imports from China and R&D Efforts

	Chinese Imports		Share of R&D	Share of
	Total	Share	Employment	Researchers
	(1)	(2)	(3)	(4)
1993-1999	2.82	0.01	0.06	0.03
2000-2008	10.10	0.03	0.07	0.04
2009-2016	20.85	0.04	0.09	0.06

Notes: rows present the average over the period. Column 1 is in billions of Euros. Column 2 is the share on total world imports of France. Source: French Customs Data and French R&D Survey.

median sector with high and low import penetration, where values are normalized to the initial year (1993). The differential pattern of growth between sectors is remarkable. Sectors facing high import competition increased relatively more their share of R&D employment and researchers. By 2016, the gap between high and low import penetration sectors was more than 50%.

Figure 2: France: Import Penetration and R&D Efforts



These patterns in the data indicate a coincidence between the expansion in import penetration from China and the increase in the employment allocated to R&D by firms in France. However, they can not establish causality as import penetration could encourage firms to undertake further innovation efforts or, inversely, higher innovation efforts can affect import penetration. Our next step is then to attempt to establish causality by linking the increase in the competitiveness of China in the world economy and the expansion in French firms' R&D activities. We turn then to describe our identification strategy.

4 Empirical Analysis

4.1 Identification Strategy

This section presents the identification strategy and discusses possible concerns regarding the empirical analysis, for example, simultaneity bias, previous growth trends, differences in industrial patterns of growth and reverse causality.

The identification strategy of the effect of import competition on French firms' R&D efforts and export behavior is based on their differential exposure to the supply-driven shock driven by the joining of China to the WTO in 2001. We exploit two sources of variation to identify the Chinese shock. Our first source of variation is based on yearly changes on import penetration from China between 1993 and 2016. Our second source of variation is the heterogeneity in import penetration across four-digit NACE industries. These two sources of variation allow us to identify the differential exposure of French firms to import competition across time and narrowly defined sectors.

The relationship between R&D efforts and import competition could be addressed by estimating an OLS regression of firms' employment in R&D on the change in the sector's import penetration at the four-digit industries. The estimated coefficient of this regression would indicate whether firms change their R&D efforts in response to increased import penetration in the industry. However, this regression could be subject to omitted variable bias as unobserved local technology shocks could affect firms' imports demand. To address this concern, we employ our measure of exposure to import penetration from China of other high-developed economies. The instrument's relevant assumption is that high-income countries are similarly exposed to the expansion in Chinese exports. The instrument's exogeneity assumption is that four-digit industry shocks in these countries are uncorrelated with industry shocks in France across time. We follow a similar strategy to analyze firms' export behavior.[10]

A main assumption of the empirical strategy is that, prior to the Chinese shock, sectors more exposed to import penetration upon it did not have a differential trend in technology adoption and export behavior. If this was the case, we could be attributing the effect of the trade liberalization to pre-existing trends. To assess the parallel trend hypothesis, we compute the average growth rate for the main variables analyzed at four-digit NACE industry between: 1985-1990 and 1985-1999, and compare them with the growth rate in Chinese imports in France between 2000-2016. Table 5 presents these correlations and shows that neither the share of R&D employment, share of researchers, the number of product exported, the quality of exported products, exports, labor productivity or employment in the pre-liberalization period associate with a differential expansion of Chinese import penetration. This lack of correlation suggests that sectors more exposed to the Chinese trade liberalization were not experiencing a differential pattern of investment in technology

[10]Importantly, the OECD countries considered in our analysis represent in total less than 5% of French export and imports. This suggests a low level of trade integration between France and these economies, which limits the possible channels of transmission of industry shocks and argues in favor of the exogeneity of our instrument.

or export growth before it and supports the parallel trend assumption.[11]

Table 5: Sectoral Previous Trends

	Δ Share of R&D Employment	Δ Share of Researchers	Δ # of Exported Products	Δ Product Quality	Δ Exports	Δ Labor Productivity	Δ Employment
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Panel A. Period 1985-1990						
Δ Chinese Imports 2000-2016	1.412	2.275				0.461	0.361
	(1.029)	(1.618)				(0.811)	(0.774)
	Panel B. Period 1985-1999						
Δ Chinese Imports 2000-2016	-1.158	1.308	0.234	2.156	1.979	5.722	0.781
	(0.910)	(1.448)	(3.659)	(3.940)	(1.912)	(6.546)	(0.745)

Note: *, **, *** significant at 10, 5, and 1 percent. Std. errors in parenthesis. The change is computed as the average change of the four-digit NACE industry in the period. Source: French R&D Survey and Customs data.

The previous paragraph discussed concerns about sectors' pre-existing growth trends in technology adoption. However, if Chinese imports were correlated with some firm or industry characteristics that could imply different pattern of investment in technology, it would be necessary to control for them to rule our possible sources of bias. We estimate equations in first differences, so all time-invariant characteristics are differenced out. Yet if firms or sectors with different initial characteristics were on different trends, the estimated coefficient could capture some omitted time-dependent variable. To tackle this issue, we include firm fixed effects in our first difference regressions, which de-means firms' growth across time. These fixed effects allow us to estimate the differential impact of Chinese imports *within firms* and to control for firm-level differential trends.

One important concern regarding the Chinese trade openness is that it might not have only encouraged Chinese imports to France, but also an increase of French exports to China. The expansion in market size could have induced French firms to increase their R&D efforts and, hence, it is important to control for this market size effect. However, since increases in R&D efforts could lead to export increases independently of the Chinese trade openness, we cannot use French export as a control for market size. Instead, we use industry exports to China at four-digit NACE industries from main fourteen European countries –UK, Germany, Italy, Spain, Portugal, Belgium, Greece, Netherlands, Sweden, Austria, Denmark, Ireland, Luxembourg and Finland– over 1993-2016.[12] The identification assumption is that EU industry exports to China are correlated with French exports, but French R&D efforts do not associate with increases in EU exports to China.

Even though the preceding points address the concerns over differential growth trends across firms and industries, any aggregate shocks that could affect firms' R&D efforts differentially could bias the results. To account for these shocks, we control for the GDP growth and unemployment rate in the EU and time dummies to controls for aggregate shocks as the financial crisis in 2008 and 2009.

Finally, note that the general context around the joining of China to the WTO is likely to be

[11]Note that since the trade data only starts in 1993, we can only check the correlation for the period 1993-1999.
[12]These countries constitute EU(15) except for France.

exogenous with respect to the main outcome that we analyze, that is, changes in French firms' R&D efforts. Between 1993 and 1999, the share of imports and exports from China in France was less than one percent, and the share of firms importing from and exporting to China was five and two percent of trading firms, respectively, as shown in Tables 4 and A2 (in Appendix A). It is then unlikely that political pressure of French firms could have been behind this process and cause reverse causality concerns.

4.2 Impact on R&D Efforts

We analyze the differential impact of the supply-shock produced by the trade openness in China on French firms' R&D and innovation activities by considering the following regression:

$$y_{it} = \beta_1 \, IP_{jt}^{FC} + \gamma X_{jt}^{EU} + \mu_i + \eta_t + \varepsilon_{ijt}, \tag{4}$$

where i, j and t denote firm, four-digit NACE industries and year; y_{it} is the yearly growth rate of the selected measure of R&D effort and IP_{jt} is the yearly change in Chinese imports to France at the four-digit NACE industry, weighted by the initial share of total world imports in sector j in France. X_{jt}^{EU} is the yearly growth rate of four-digit industry exports of European countries to China that controls for the increase in market size in French firms' export. Our within firm estimator includes firm-fixed effects $-\mu_i-$ to capture all firm and industry time-invariant characteristics and estimate the evolution of firms over time. To control for macro-aggregate shocks, we include time dummies, the growth rate of GDP and the unemployment rate in the EU. To avoid serial correlation in the error terms, we cluster the standard errors at the four-digit NACE industry. The coefficient of interest is β_1 and captures the impact of Chinese import penetration on firms' outcomes.

Since the growth in Chinese imports could be related to unobserved industry-level shocks in France, we employ instrumental variables to evaluate potential endogeneity concerns. We estimate the following reduced-form for the first stage of the model

$$IP_{jt}^{FC} = \beta_0 \, IP_{jt}^{OC} + \gamma X_{jt}^{EU} + \mu_i + \eta_t + \varepsilon_{ijt}, \tag{5}$$

where IP_{jt}^{OC} is the yearly change in Chinese imports to selected high-income countries in four-digit NACE industry, weighted by the initial share of total world imports in the sector j. Standard errors are clustered at the firm-level. We expect that β_0 to be positive, capturing the supply-driven component of Chinese openness to trade in developed economies.

OLS Estimates

Panel A in Table 6 presents the results of the OLS estimates on firms' R&D efforts. Column 1 displays the estimated coefficient of a regression on the share of R&D employment only on our import penetration measure for France and firm fixed-effects. The coefficient is highly statistically significant and positive indicating that French firms facing more import competition allocate more employees to R&D activities. In particular, it implies that a 10 percentage point increase in Chinese import penetration associates with a 3.1% increase in the share of R&D employment. To assess the market size effect, in column 2, we regress R&D efforts on EU exports to China, without including import competition into the analysis. Interestingly, the estimated coefficient is positive, but non-statistically significant suggesting that the expansion in the market size does not affect French firms' R&D efforts. Column 3 estimates equation (4) where both the import penetration and market size measures are included into the analysis. The estimated coefficients are similar on magnitude and confirm our results of columns 1 and 2. Chinese import competition encourages French firms to allocate more employment to R&D, while the market size effect remains non-significant. Finally, column 4 includes the aggregate controls and confirms these results.

Columns 5-8 present the results for the share of researchers. Column 5 –where only the import penetration measure is included– indicates that 10 percentage point increase in import penetration raises the share of researchers by 2.2%. Similarly to column 2, the market size effect is not statistically significant, confirming that the expansion in the share of researchers is not driven by exports. These results hold true and when including both import penetration and market size, and controlling for aggregate shocks (columns 7 and 8).

Columns 9-12 report the results for product innovation. Just like the previous trends, import penetration associates with increases in firms' probability of conducting product innovation. In particular, after the inclusion of all controls in column 12, the estimated coefficient indicates that a 10 percentage point increase in import penetration raises the probability of investing in product innovation by 1.7%. As above, the market size effect remains non-significant.

Instrumental Variables Estimates

A concern with the OLS estimates – presented in Panel A – is the potential endogeneity of Chinese imports arising from unobserved industry-level technology shocks. The direction of the bias could well be positive or negative depending on the nature of the unobserved shock. For example, consider a local industry that faces a positive technology shock and becomes more competitive in the world economy. As foreign firms find it harder to compete, imports could decrease and the OLS estimator could be downward biased. Inversely, a negative demand shock reducing French firms' innovation activities could create an upward bias. Ultimately, the direction of the bias is an empirical question and is understood with the implementation of instrumental variables.

Panel B in Table 6 presents the instrumental variables results. Columns 1-4 report the results on the share of R&D employment and show that the estimated coefficients remain positive and highly statistically significant. After the inclusion of all controls in column 4, the coefficient implies that a 10 percentage point increase in import penetration raises the share of R&D employment by 11.3%.

Table 6: Impact on R&D Efforts

	ΔShare of Empl. in R&D				Δ Share of Researchers				Product Innovation			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	Panel A. OLS											
$\Delta\ IP_j^F$	0.313***		0.311***	0.324***	0.226**		0.227**	0.211**	0.142**		0.140**	0.174***
	(0.101)		(0.101)	(0.103)	(0.106)		(0.106)	(0.098)	(0.066)		(0.066)	(0.066)
Δ EU exports to China_j		1.568	1.345	1.256		0.021	-0.141	-0.242		1.196	1.079	1.012
		(2.034)	(2.024)	(2.029)		(2.079)	(2.074)	(2.486)		(2.051)	(2.051)	(2.052)
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Aggregate controls				Yes				Yes				Yes
R^2	0.096	0.096	0.096	0.097	0.102	0.102	0.102	0.103	0.439	0.439	0.439	0.440
N	52,847	52,847	52,847	52,847	52,847	52,847	52,847	52,847	52,000	52,000	52,000	52,000
	Panel B. Instrumental Variables											
$\Delta\ IP_j^F$	0.989***		0.983***	1.127***	0.779**		0.783**	0.884**	0.592*		0.789*	0.654*
	(0.324)		(0.325)	(0.348)	(0.354)		(0.355)	(0.382)	(0.355)		(0.412)	(0.397)
Δ EU exports to China_j			0.865	0.705			-0.538	-0.704			0.576	0.648
			(2.019)	(2.025)			(2.070)	(2.074)			(2.247)	(2.246)
Firm FE	Yes		Yes	Yes		Yes	Yes	Yes	Yes		Yes	Yes
Aggregate controls				Yes				Yes				Yes
N	52,847	52,847	52,847	52,847	52,847	52,847	52,847	52,847	52,000	52,000	52,000	52,000
	Panel C. First Stage											
$\Delta\ IP_j^{OC}$	3.078***		3.068***	2.852***	3.078***		3.068***	2.852***	2.496***		2.294***	2.378***
	(0.146)		(0.147)	(0.143)	(0.146)		(0.147)	(0.143)	(0.174)		(0.183)	(0.177)
Δ EU exports to China_j			0.446***	0.437***			0.446***	0.437***			0.513***	0.526***
			(0.084)	(0.071)			(0.084)	(0.071)			(0.080)	(0.082)
F-stat	443.1029		437.8403	395.5021	443.1029		437.8403	395.5021	205.5125		157.7981	179.4619

Notes: *, **, *** significant at 10, 5, and 1 percent. Std. errors in parenthesis. Period 1993-2016. Aggregate controls are GDP growth and unemployment rate in the European Union and a dummy for the Global financial crisis in 2008-2009. Source: R&D Survey and Customs data.

The estimated coefficients for the share of researchers – reported in columns 5-8 – are positive and highly statistically significant, confirming that import penetration leads firms to increase their share of researchers. Finally, just like the above trends, IV results indicate that firms have a higher probability of conducting product innovation in sectors facing more import competition (column 9-12). The first stage results are presented in Panel C, which show that Chinese imports to other developed economies are correlated with Chinese imports to France and the instrument is relevant for the analysis. All F-stat are significantly high.

Appendix A.2 presents a full set of robustness tests. Table A3 presents two other proxys for firms' innovation efforts: R&D expenditures and patents. Just like the previous trends, the OLS and the IV estimators indicate that firms facing more import competition from China increase their R&D expenditures and probability of patenting differentially.

4.3 Impact on Export Activities

The previous section showed that firms facing high Chinese import competition increased their R&D efforts differentially by reallocating labor towards R&D activities and undertaking more product innovation. In this section, we assess whether this higher innovation efforts translated into an expansion on firms' exports. We focus on three indicators of firms' export patters: number of products exported, product quality and value of exports, and re-estimate (4) using these indicators as outcome variables.

Results are presented in Table 7. Columns 1-4 in Panel A shows the OLS estimates of the number of products exported on import competition. The coefficients are positive and statistically significant across all regressions. After the inclusion of all controls in column 4, the coefficient implies that a 10 percentage point increase in import penetration associates with a 2% increase in the number of products exported.

Remarkably, firms not only have increased the number of products exported, but also the quality of their products, as suggested in columns 5-8. The estimated coefficients on the product quality are highly statistically significant in all specifications and, after the inclusion of all controls in column 8, the coefficient implies that a 10 percentage point increase in import competition raises the quality of exported products by 2.5%.

The expansion in the number of exported products and their quality was also reflected in an increase of exports. Columns 9-12 shows that firms facing more import competition differentially increased their total exports relatively more. Column 12 indicates that a 10 percentage point increase in import competition raises total exports by 4%.

Panel B presents the IV estimates and shows that all coefficients remain positive and highly statistically significant across all specifications. As expected, the first stage coefficients are positive and significant and F-stat confirms that import penetration to other developed economies is a good instrument.

These results suggest that French firms facing higher import competition from China increased their R&D efforts and that, in turn, they expanded their exports by increasing the number of exported products and the quality of these products. We next assess the effect of import competition on firms' performance.

4.4 Impact on Productivity and Employment

To evaluate whether the increase in firms' R&D efforts is translated into higher growth, we consider here two indicators of firms' performance: labor productivity and employment.

Table 8 presents the estimated coefficients of equation (4) when labor productivity and employment are the outcome variables. In line with the expansion in R&D efforts, the estimated coefficients on labor productivity are positive and highly statistically significant in all specifications, indicating that French firms facing more import competition increased their labor productivity (Columns 1-4 of Panel A). After the inclusion of all controls in column 4, the coefficient implies that a 10 percentage point increase in import competition raises firms' labor productivity by 3.3%.

Import penetration also associates with increases in employment, as shown in columns 5-8. A 10 percentage point increase import penetration associates with a 3.3% expansion in firms' employment. Interestingly, whilst the market size effect was non-statistically significant on the firms' R&D

Table 7: Impact on Export Activities

	Δ # of Products Exported				Δ Product Quality				Δ Exports			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	Panel A. OLS											
$\Delta\ IP_j^F$	0.366***		0.359***	0.206*	0.248**		0.252**	0.247**	0.570**		0.570**	0.403*
	(0.109)		(0.109)	(0.111)	(0.114)		(0.114)	(0.118)	(0.242)		(0.242)	(0.230)
Δ EU exports to China$_j$		7.652***	7.421***	7.682***		-3.390	-3.548	-3.535		0.998	0.630	0.883
		(2.164)	(2.155)	(2.145)		(2.861)	(2.863)	(2.865)		(5.691)	(5.692)	(5.689)
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Aggregate controls				Yes				Yes				Yes
R^2	0.084	0.084	0.085	0.087	0.143	0.143	0.143	0.143	0.111	0.111	0.111	0.113
N	47,139	47,139	47,139	47,139	42,093	42,093	42,093	42,093	47,139	47,139	47,139	47,139
	Panel B. Instrumental Variables											
$\Delta\ IP_j^F$	1.770***		1.728***	1.365**	0.765**		0.784**	0.825**	1.665*		1.657*	1.681*
	(0.547)		(0.548)	(0.585)	(0.386)		(0.387)	(0.419)	(0.950)		(0.953)	(0.955)
Δ EU exports to China$_j$			6.537***	6.960***			-3.292	-3.300			1.284	1.485
			(2.150)	(2.149)			(2.855)	(2.858)			(5.695)	(5.692)
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Aggregate controls				Yes				Yes				Yes
N	47,139	47,139	47,139	47,139	42,093	42,093	42,093	42,093	47,139	47,139	47,139	47,139
	Panel C. First Stage											
$\Delta\ IP_j^{OC}$	3.190***		3.181***	2.953***	3.174***		3.166***	2.943***	3.185***		3.176***	3.169***
	(0.158)		(0.159)	(0.156)	(0.163)		(0.164)	(0.161)	(0.063)		(0.063)	(0.063)
Δ EU exports to China$_j$			0.413***	0.408***			0.410***	0.406***			0.401***	0.379***
			(0.083)	(0.071)			(0.084)	(0.072)			(0.118)	(0.117)
F-stat	405.8767		401.8545	360.7313	377.9798		374.3957	335.0874	2559.981		2543.49	2558.579

Notes: *, **, *** significant at 10, 5, and 1 percent. Std. errors in parenthesis. Period 1993-2016. Aggregate controls are GDP growth and unemployment rate in the European Union and a dummy for the Global financial crisis in 2008-2009. Source: R&D Survey and Customs data.

efforts, it is positive and highly statistically significant on employment. The estimated coefficient is also significant in economic terms: a 10 percentage point increase in exports to China increase firms' employment by 44%. The IV results –presented in Panel B– confirm these trends.

4.5 Impact of Import Competition across Sectors

The above sections indicated that, for the average sector, Chinese import penetration deepened market competition and led firms to increase their R&D efforts in order to expand the quality and number of exported products. However, this impact could be heterogeneous across sectors and could depend on the sector's competitiveness. Consider, for example, a sector in which French firms were not competitive with respect to their Chinese counterparts prior to the shock. Then, deeper Chinese competition could have lowered their profits, undermined their incentives to invest in technology and, hence, their performance in the export market. Inversely, in sectors where French firms were already competitive, deeper competition could have led them to increase their R&D efforts to escape competition. In this section, we test this hypothesis by computing sectors' comparative advantage and assessing whether the pro-competitive channel works differently in sectors in which firms were already competitive in the world economy.

With this end, we follow Costinot, Donaldson, and Komunjer (2011), Levchenko and Zhang

Table 8: Impact on Productivity and Employment

	Δ Labor Productivity				Δ Employment			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Panel A. OLS							
Δ IP_j^F	0.523***		0.524***	0.329***	0.350***		0.345***	0.327***
	(0.117)		(0.117)	(0.115)	(0.048)		(0.048)	(0.050)
Δ EU exports to China$_j$		-0.631	-1.002	-0.890		4.473***	4.226***	4.484***
		(2.143)	(2.138)	(2.133)		(1.525)	(1.526)	(1.513)
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Aggregate controls				Yes				Yes
R^2	0.080	0.080	0.080	0.081	0.152	0.151	0.152	0.161
N	52,847	52,847	52,847	52,847	52,847	52,847	52,847	52,847
	Panel B. Instrumental Variables							
Δ IP_j^F	1.731***		1.744***	1.412**	0.442*		0.413*	0.285*
	(0.541)		(0.544)	(0.576)	(0.234)		(0.236)	(0.166)
Δ EU exports to China$_j$			-1.867	-1.633			4.178***	3.210***
			(2.150)	(2.152)			(1.542)	(0.997)
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Aggregate controls				Yes				Yes
N	52,847	52,847	52,847	52,847	52,847	52,847	52,847	52,847
	Panel C. First Stage							
Δ IP_j^{OC}	3.133***		3.123***	2.903***	3.078***		3.068***	2.853***
	(0.149)		(0.150)	(0.146)	(0.146)		(0.147)	(0.146)
Δ EU exports to China$_j$			0.448***	0.444***			0.446***	0.421***
			(0.083)	(0.071)			(0.084)	(0.071)
F-stat	440.7328		435.5705	392.7371	443.1029		437.8403	381.8507

Notes: *, **, *** significant at 10, 5, and 1 percent. Std. errors in parenthesis. Period 1993-2016. Aggregate controls are GDP growth and unemployment rate in the European Union and a dummy for the Global financial crisis in 2008-2009. Source: R&D Survey and Customs data.

(2016) and Hanson, Lind, and Muendler (2015) among others, and construct a measure of revealed comparative advantage in each four-digit NACE industry as

$$CA_{jt}^F = \frac{\frac{X_{jt}^F}{\sum_j X_t^F}}{\frac{X_{jt}^W}{\sum_j X_t^W}},$$

where X_{jt}^F represents France's export in sector j at the four-digit NACE industry and X_{jt}^W represents the world's export in that sector. To avoid endogeneity concerns, we compute this measure for the pre-WTO period (1993-2000). We create a dummy variable $-RCA_j^F-$ indicating whether the sector had a comparative advantage with the rest of the world (e.g. $CA_{j,93-00}^F > 1$), and interact it with our measure of import penetration. We next estimate the following regression

$$y_{it} = \beta_1 \, IP_{jt}^{FC} + \beta_2 (RCA_j^F \text{ x } IP_{jt}^{FC}) + \gamma X_{jt}^{EU} + \mu_i + \eta_t + \varepsilon_{ijt}. \qquad (6)$$

The coefficient β_1 captures the pro-competitive channel across sectors in which France had a revealed comparative disadvantage (e.g. $RCA_j^F = 0$). A positive coefficient implies that firms in those sectors expand following increases in Chinese import competition. Our coefficient of interest is β_2, which absorbs the differential impact of import penetration in sectors with a revealed comparative advantage prior to the WTO. More precisely, it reflects whether firms in sectors in which France had comparative advantage prior to the shock expand relatively more than those in which France had comparative disadvantage.

The estimated coefficients are presented in Table 9 and indicate that the pro-competitive effects reported in the previous sections are mainly driven by sectors in which France had already revealed comparative advantage prior to the China shock. In particular, the OLS estimates of our indicators of R&D efforts – share of R&D employment, share of researchers and product innovation – are only positive and statistically significant in sectors with a revealed comparative advantage, while they are insignificant in sectors with comparative disadvantage (Panel A, columns 1-3). The coefficients on the export market – number of products exported, product quality and total exports – confirm this differential pattern of growth (columns 4-6). Panel B presents the IV estimates and confirms the differential expansion of sectors in which France had a comparative advantage.

Table 9: Impact of Import Competition across Sectors

	Δ Share of Empl. in R&D (1)	Δ Share of Researchers (2)	Product Innovation (3)	Δ # Products Exported (4)	Δ Product Quality (5)	Δ Exports (6)	Δ Labor Productivity (7)	Δ Empl. (8)
				Panel A. OLS				
RCA^F_j x Δ IP^F_j	0.372**	0.394**	0.274*	0.688*	0.769*	0.683*	0.845**	0.321*
	(0.188)	(0.194)	(0.143)	(0.409)	(0.405)	(0.407)	(0.422)	(0.193)
Δ IP^F_j	0.148	0.114	0.082	-0.110	-0.460**	0.093	-0.063	0.283***
	(0.096)	(0.131)	(0.070)	(0.256)	(0.202)	(0.247)	(0.185)	(0.105)
Δ EU exports to China$_j$	0.482	-0.128	-0.123	7.399***	-5.635	-6.037	0.295	4.428***
	(2.113)	(3.021)	(1.872)	(2.104)	(4.283)	(5.766)	(2.143)	(1.533)
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Aggregate controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.106	0.103	0.482	0.115	0.074	0.177	0.112	0.165
N	52,847	52,847	52,000	47,139	42,093	47,139	52,487	52,487
				Panel B. Instrumental Variables				
RCA^F_j x Δ IP^F_j	1.899**	1.305*	4.480***	2.085*	1.401*	3.302*	5.922***	0.751*
	(0.963)	(0.743)	(1.374)	(1.264)	(0.809)	(1.884)	(1.721)	(0.412)
Δ IP^F_j	0.299	0.689***	0.190	1.055**	0.300*	-0.900	1.239**	0.108
	(0.411)	(0.165)	(0.404)	(0.415)	(0.174)	(0.703)	(0.595)	(0.169)
Δ EU exports to China$_j$	0.649	-1.534	1.540	5.047***	-1.243	1.692	-0.523	2.472***
	(1.924)	(2.200)	(2.096)	(1.814)	(2.682)	(2.918)	(2.250)	(0.875)
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Aggregate controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	52,847	52,847	52,000	47,139	42,093	47,139	52,487	52,487

Notes: *, **, *** significant at 10, 5, and 1 percent. Std. errors in parenthesis. Period 1993-2016. Aggregate controls are GDP growth and unemployment rate in the European Union and a dummy for the Global financial crisis in 2008-2009. We compute the RCA as $CA^F_{jt} = \frac{X^F_{jt}}{\sum_j X^F_t} / \frac{X^W_{jt}}{\sum_j X^W_t}$. Source: R&D Survey and Customs data.

Firm-Level Analysis: Taking Stock

Sections 4.2-4.5 evaluated the pro-competitive channel of Chinese imports into French firms' R&D efforts and export patterns. First, we showed that import penetration led to a reallocation of employment towards innovation activities, as the share of R&D employment and share of researchers increased in sectors facing deeper competition of Chinese products. Notably, in those sectors firms engage in more product innovation. Second, we showed that the expansion in R&D translated into an improvement in firms' performance in the export market. In sectors with higher import penetration, firms increased the number of products exported, the quality of their exported products and their total exports. Consistent with this expansion, we showed that these firms increased their labor productivity and employment. Finally, our results indicate that there is substantial heterogeneity in firms' responses. The observed expansion in R&D efforts and export market was principally driven by sectors in which France had a revealed comparative advantage prior to the China shock.

4.6 Evolution of Sectoral RCA

Our previous results showed that pro-competitive forces led firms to increase the quality and the number of products exported. We turn now to study whether this expansion in the export market reflects on changes in the revealed comparative advantage of the French activities in two steps. We first assess whether deeper import competition associates with improvements in sectors' comparative advantage. We then check whether this effect is heterogeneous across sectors as a function of sectors' initial comparative advantage.

To assess whether import penetration correlates with changes in sectors' comparative advantage, we estimate

$$CA_{jt}^{F} = \beta_1 IP_{jt}^{FC} + \gamma X_{jt}^{EU} + \mu_i + \eta_t + \varepsilon_{ijt}, \qquad (7)$$

where $CA_{jt}^{F} = \frac{X_{jt}^{F}}{\sum_j X_t^F} / \frac{X_{jt}^{W}}{\sum_j X_t^W}$ is our measure of revealed comparative advantage constructed at four-digit NACE industries between 1993 and 2016. Note that our CA_{jt}^{F} measure excludes China on total world exports to avoid simultaneity bias between the dependent and independent variables.[13] Our coefficient of interest is β_1 which absorbs the effect of import penetration in the sectors' comparative advantage.

Table 10 presents the results. The estimated coefficients for our OLS estimate of equation (7) are presented in Panel A and indicate that Chinese import penetration associates with increases in the revealed comparative advantage of the sectors. The estimated coefficients are positive and statistically significant across all specifications (columns 1-4). Panel B reports our IV estimators and confirms these results. After the inclusion of all controls in column 4, the IV coefficient is statistically significant and implies that a 10 percentage point increase in import penetration raises the comparative advantage of a sector by 34%. It is worth noting on the standard errors of the coefficients, which are quite high and suggest that there is substantial heterogeneity in sectors' responses, as we describe below.

[13]Note that import penetration –IP_{jt}^{FC}– reflects Chinese exports, which would also be included in the denominator of the comparative advantage measure.

Our results above showed that firms' R&D and export responses to Chinese import competition were stronger in sectors where France had a revealed comparative advantage prior to the China shock (Section 4.5). We now go one step forward and check whether the evolution of the comparative advantage differs as a function of sectors' initial comparative advantage. With this end, we break down sectors by having initial revealed comparative advantage/disadvantage, and facing high/low import penetration from China. In particular, we divide sectors into four bins: sectors with an initial revealed comparative advantage and facing high import penetration, sectors with a comparative disadvantage and facing high import penetration, sectors with a comparative advantage and facing low import penetration, and sectors with a comparative disadvantage and facing low import penetration.[14]

Table 10: Evolution of Sectoral RCA

	Δ Sectoral RCA			
	(1)	(2)	(3)	(4)
	Panel A. OLS			
Δ IP^F_j	0.110*		0.110*	0.108*
	(0.063)		(0.063)	(0.064)
Δ EU exports to China_j		0.227	0.133	0.259
		(6.159)	(6.158)	(6.159)
Sector FE	Yes	Yes	Yes	Yes
Aggregate controls				Yes
R^2	0.059	0.058	0.059	0.060
N	4,632	4,632	4,632	4,632
	Panel B. Instrumental Variables			
Δ IP^F_j	3.217*		3.235*	3.433*
	(1.891)		(1.907)	(2.019)
Δ EU exports to China_j			-1.121	-0.437
			(6.709)	(6.733)
Sector FE	Yes	Yes	Yes	Yes
Aggregate controls				Yes
N	4,632	4,632	4,632	4,632
	Panel C. First Stage			
Δ IP^{OC}_j	2.154***		2.142***	2.045***
	(0.578)		(0.579)	(0.576)
Δ EU exports to China_j			0.351	0.216
			(0.941)	(0.934)
F-stat	13.89199		13.68718	12.62131

Notes: *, **, *** significant at 10, 5, and 1 percent. Std. errors in parenthesis. Columns 1-4 compute the RCA as $CA^F_{jt} = \frac{X^F_{jt}}{\sum_j X^F_t} / \frac{X^W_{jt}}{\sum_j X^W_t}$ and exclude China in the denominator to avoid simultaneity bias. Period 1993-2016. Aggregate controls are GDP growth and unemployment rate in the European Union and a dummy for the Global financial crisis in 2008-2009. Source: French Customs data.

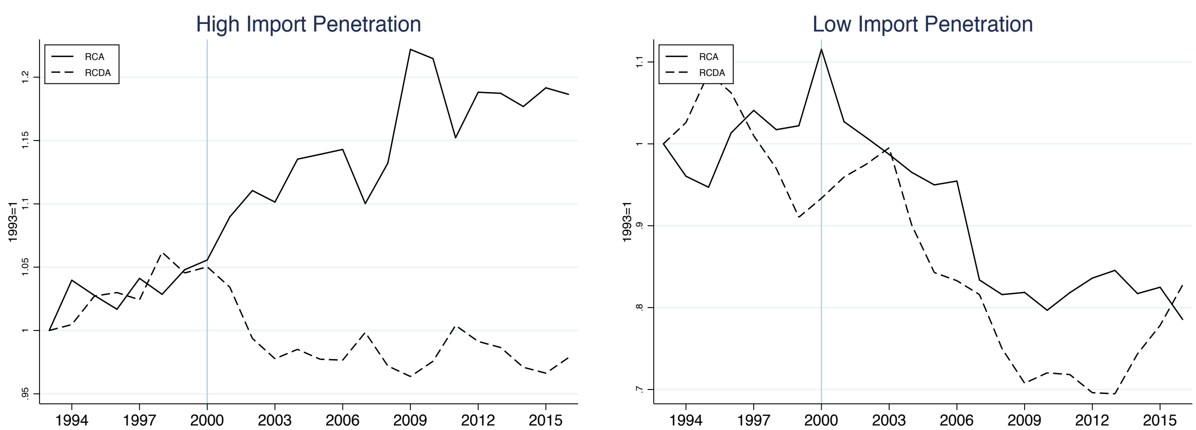
Figure 3 plots the evolution of the revealed comparative advantage for these four bins of sectors, where the values are normalized to the initial year (1993). The figure on the left shows the evolution of sectors with initial comparative advantage and disadvantage and facing high import competition from China. The different pattern of growth is striking. Sectors with an initial comparative

[14] We define a sector facing high/low import penetration, if the Chinese import growth was higher than the median growth of the economy (see also Section 3).

advantage experienced a ten percent increase in the comparative advantage after the shock (2000-2016), whereas sectors with a comparative disadvantage lose competitiveness in the world economy and worsen their comparative disadvantage. It is important to remark on the pre-China shock period –1993-2000– when the comparative advantage of both types of sectors was evolving at the same pace. It is only after the China shock when the evolution of their comparative advantage started to differ. The right graph of Figure 3 plots the evolution of the comparative advantage for sectors facing low import competition. Remarkably, the comparative advantage of sectors with initial comparative advantage and disadvantage evolves in parallel and does not show any differential pattern of growth.

These results highlight the pro-competitive forces of trade that, through higher R&D efforts, led firms to increase the quality and number of the product exported and improve the competitiveness in the world economy. Nonetheless, not all are good news. These results veil substantial heterogeneity. Highly competitive sectors with a comparative advantage show the largest innovation and export market responses, which lead them over time to increase their comparative advantage in the world economy. Instead, sectors with an initial disadvantage were not able to respond to the increased competition and experienced a decrease in their competitiveness.

Figure 3: Impact across Sectors: Evolution of Revealed Comparative Advantage



5 Conclusion

This paper shows that import penetration can induce firms to increase their R&D efforts in order to differentiate their products and escape competition. Product quality improvements translate into increases in firms' exports. These effects are stronger in sectors in which France had comparative advantage prior to the increase in import penetration. We have documented this mechanism using firm-level data on R&D and exports from France over more than three decades. We have employed the entry of China to the WTO in 2000 to identify the rise in foreign competition.

We started by showing that increased Chinese import penetration led French firms to expand their share of R&D employment, share of researchers and their probability of conducting product innovation. Higher innovation efforts translated into increases in the number and quality of products exported. At the sector level, the expansion in exports resulted in an improvement of the revealed comparative advantage. Yet these results veil large heterogeneity across sectors. The expansion in exports and revealed comparative advantage are driven by sectors in which France had already a comparative advantage prior to the China shock. In these sectors, firms increased their innovation efforts and number and quality of exported products differentially.

Our results indicate that the impact of import penetration from low income countries differs substantially across sectors and depends on the initial competitiveness of sectors and firms in the word economy. Firms and sectors internationally competitive escape competition by differentiating their products and improving their quality of production. On the contrary, firms with comparative disadvantage face tougher competition and risk to exit. On the aggregate, the consequences of import competition depends on the distribution of sectoral comparative advantage.

References

Aghion, P., A. Bergeaud, M. Lequien, and M. J. Melitz (2018): "The Impact of Exports on Innovation: Theory and Evidence," Working Paper 24600, National Bureau of Economic Research.

Aghion, P., N. Bloom, R. Blundell, R. Griffith, and P. Howitt (2005): "Competition and Innovation: an Inverted-U Relationship*," *The Quarterly Journal of Economics*, 120(2), 701–728.

Aghion, P., and P. Howitt (1992): "A Model of Growth through Creative Destruction," *Econometrica*, 60(2), 323–51.

Akcigit, U., S. T. Ates, and G. Impullitti (2018): "Innovation and Trade Policy in a Globalized World," Working Paper 24543, National Bureau of Economic Research.

Amiti, M., and A. K. Khandelwal (2013): "Import Competition and Quality Upgrading," *The Review of Economics and Statistics*, 95(2), 476–490.

Atkeson, A., and A. T. Burstein (2010): "Innovation, Firm Dynamics, and International Trade," *Journal of Political Economy*, 118(3), 433–484.

Autor, D., D. Dorn, G. H. Hanson, G. Pisano, and P. Shu (2016): "Foreign Competition and Domestic Innovation: Evidence from U.S. Patents," NBER Working Papers 22879, National Bureau of Economic Research, Inc.

Autor, D. H., D. Dorn, G. H. Hanson, and J. Song (2014): "Trade Adjustment: Worker-Level Evidence," *The Quarterly Journal of Economics*, 129(4), 1799–1860.

Aw, B. Y., M. J. Roberts, and D. Y. Xu (2011): "R&D Investment, Exporting, and Productivity Dynamics," *American Economic Review*, 101(4), 1312–44.

Bas, M., and V. Strauss-Kahn (2015): “Input-trade liberalization, export prices and quality upgrading,” *Journal of International Economics*, 95(2), 250–262.

Bernard, A. B., J. B. Jensen, and P. K. Schott (2006): “Survival of the best fit: Exposure to low-wage countries and the (uneven) growth of U.S. manufacturing plants,” *Journal of International Economics*, 68(1), 219 – 237.

Bernard, A. B., S. J. Redding, and P. K. Schott (2010): “Multiple-Product Firms and Product Switching,” *American Economic Review*, 100(1), 70–97.

Bloom, N., M. Draca, and J. V. Reenen (2016): “Trade Induced Technical Change? The Impact of Chinese Imports on Innovation, IT and Productivity,” *Review of Economic Studies*, 83(1), 87–117.

Bloom, N., P. Romer, S. J. Terry, and J. Van Rennen (2018): “Trapped factors and China,Äôs impact on global growth,” Discussion paper, mimeo.

Bustos, P. (2011): “Trade Liberalization, Exports, and Technology Upgrading: Evidence on the Impact of MERCOSUR on Argentinian Firms,” *American Economic Review*, 101(1), 304–40.

Cai, J., N. Li, and A. M. Santacreu (2017): “Knowledge Diffusion, Trade and Innovation Across Countries and Sectors,” Working Papers 2017-29, Federal Reserve Bank of St. Louis.

Coelli, F., A. Moxnes, and K. H. Ulltveit-Moe (2016): “Better, Faster, Stronger: Global Innovation and Trade Liberalization,” Discussion paper, National Bureau of Economic Research.

Costinot, A., D. Donaldson, and I. Komunjer (2011): “What Goods Do Countries Trade? A Quantitative Exploration of Ricardo’s Ideas,” *The Review of Economic Studies*, 79(2), 581–608.

Fieler, A. C., M. Eslava, and D. Y. Xu (2018): “Trade, Quality Upgrading, and Input Linkages: Theory and Evidence from Colombia,” *American Economic Review*, 108(1), 109–46.

Grossman, G. M., and E. Helpman (1991): “Trade, knowledge spillovers, and growth,” *European Economic Review*, 35(2-3), 517–526.

Hanson, G. H., N. Lind, and M.-A. Muendler (2015): “The Dynamics of Comparative Advantage,” Working Paper 21753, National Bureau of Economic Research.

Holmes, T., and J. Schmitz (2010): “Competition and productivity: a review of evidence,” *Annual Review of Economics*, 2, 619–642.

Hombert, J., and A. Matray (2018): “Can Innovation Help U.S. Manufacturing Firms Escape Import Competition from China?,” *The Journal of Finance*, LXXIII(5), 2003–2039.

Khandelwal, A. (2010): “The Long and Short (of) Quality Ladders,” *The Review of Economic Studies*, 77(4), 1450–1476.

Levchenko, A. A., and J. Zhang (2016): “The evolution of comparative advantage: Measurement and welfare implications,” *Journal of Monetary Economics*, 78, 96 – 111.

Lileeva, A., and D. Trefler (2010): “Improved Access to Foreign Markets Raises Plant-level Productivity For Some Plants,” *The Quarterly Journal of Economics*, 125(3), 1051–1099.

Mayer, T., M. J. Melitz, and G. I. Ottaviano (2016): “Product Mix and Firm Productivity Responses to Trade Competition,” Working Paper 22433, National Bureau of Economic Research.

Mayer, T., M. J. Melitz, and G. I. P. Ottaviano (2014): "Market Size, Competition, and the Product Mix of Exporters," *American Economic Review*, 104(2), 495–536.

Medina, P. (2018): "Import Competition, Quality Upgrading and Exporting: Evidence from the Peruvian Apparel Industry," Discussion paper, Mimeo.

Sampson, T. (2016): "Dynamic Selection: An Idea Flows Theory of Entry, Trade, and Growth," *The Quarterly Journal of Economics*, 131(1), 315–380.

Somale, M. (2014): "Comparative advantage in innovation and production," Discussion paper, Princeton, Princeton.

Verhoogen, E. A. (2008): "Trade, Quality Upgrading, and Wage Inequality in the Mexican Manufacturing Sector*," *The Quarterly Journal of Economics*, 123(2), 489–530.

Appendix A Empirical Appendix

Appendix A.1 Additional Figures and Tables

Figure A1: France: Imports from China

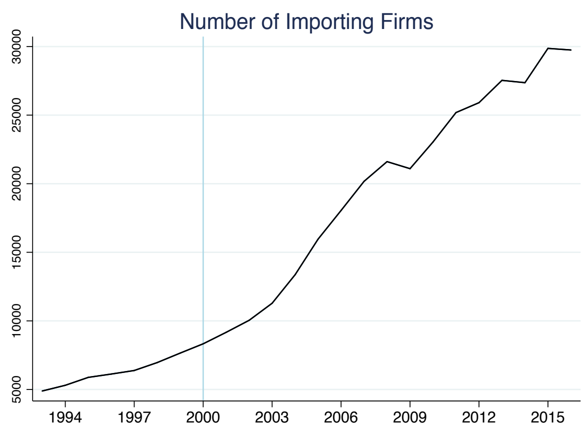


Figure A2: France: Exports to China

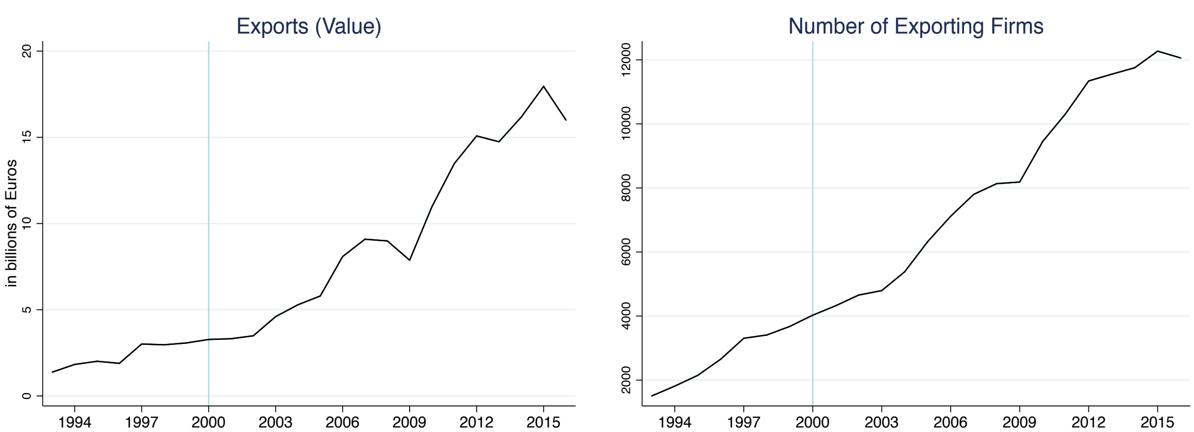
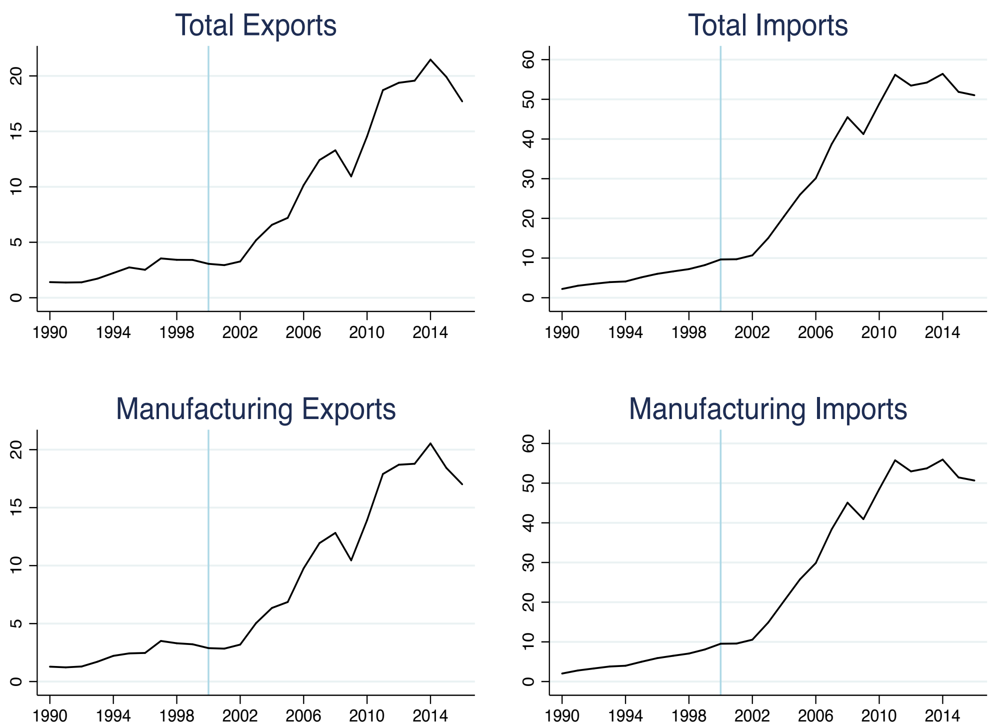


Figure A3: France: Trade with China



Note: in billions of USD. Source: UN COMTRADE.

Table A1: France: Imports from China

	Firms		Products	
	Number	Share	Number	Share
	(1)	(2)	(3)	(4)
1993-1999	6,169	0.05	3,000	0.29
2000-2008	14,220	0.12	4,551	0.46
2009-2016	26,219	0.21	5,458	0.59

Notes: rows present the average over the period. Columns 2 and 4 are the share on total world imports from China. Columns 1 and 3 present the number of firms and products. Source: French Customs Data.

Table A2: France: Exports to China

	Value		Firms		Products	
	Total	Share	Number	Share	Number	Share
	(1)	(2)	(3)	(4)	(5)	(6)
1993-1999	2.31	0.01	2,645	0.02	2,497	0.25
2000-2008	5.77	0.02	5,840	0.05	3,814	0.39
2009-2016	14.04	0.03	10,866	0.11	4,887	0.54

Notes: rows present the average over the period. Column 1 is in billions of Euros. Columns 2, 4 and 6 is the share on total world exports to France. Columns 3 and 5 present the number of firms and products. Source: French Customs Data.

Table A3: Impact on R&D Activities

	Δ R&D Expenditure				Patents			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Panel A. OLS							
$\Delta\ IP_j^F$	0.686***		0.680***	0.696***	0.164*		0.165*	0.170*
	(0.121)		(0.121)	(0.125)	(0.096)		(0.096)	(0.099)
Δ EU exports to China$_j$		5.493**	5.007**	5.225**		-0.633	-1.201	-1.119
		(2.209)	(2.199)	(2.196)		(1.776)	(1.762)	(1.731)
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Aggregate controls				Yes				Yes
R^2	0.104	0.103	0.104	0.107	0.544	0.537	0.544	0.550
N	52,847	52,847	52,847	52,847	42,304	42,304	42,304	42,304
	Panel B. Instrumental Variables							
$\Delta\ IP_j^F$	1.187**		1.154**	1.227**	0.423*		0.432*	0.609*
	(0.473)		(0.475)	(0.512)	(0.242)		(0.242)	(0.326)
Δ EU exports to China$_j$			4.668**	4.861**			-1.284	-1.265
			(2.208)	(2.209)			(1.069)	(1.042)
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Aggregate controls				Yes				Yes
N	52,847	52,847	52,847	52,847	42,304	42,304	42,304	42,304
	Panel C. First Stage							
$\Delta\ IP_j^{OC}$	3.078***		3.068***	2.852***	3.019***		3.018***	2.768***
	(0.146)		(0.147)	(0.143)	(0.710)		(0.715)	(0.805)
Δ EU exports to China$_j$			0.446***	0.437***			0.054	0.066
			(0.084)	(0.071)			(0.366)	(0.327)
F-stat	443.1029		437.8403	395.5021	18.07443		17.84137	11.81841

Notes: *, **, *** significant at 10, 5, and 1 percent. Std. errors in parenthesis. Period 1993-2016. Aggregate controls are GDP growth and unemployment rate in the European Union and a dummy for the Global financial crisis in 2008-2009. Source: R&D Survey and Customs data.

Appendix A.2 Data

This section describes the data used in the paper and provides the links to the data producers.

Firm-level data

Our firm-level data on French firms comes from: (i) the Survey on R&D and Innovation Activities ("Enquête annuelle sur les moyens consacrés à la recherche et au développent dans les entreprises") is produced by the French Ministry of Education between the period 1980-2016, (ii) the customs data on export and imports, produced annually by the French Customs Office ("Données import/export du commerce extérieur") since 1993, and (iii) the balance sheet data ("Données entreprises") is produced by the National Statistical Institute (INSEE) over the period 1993 to 2016. This data is not available to the general public and can only be accessed by permision of the Comité du Secret Statistic. Guidelines for gaining such permission are available at: https://www.comite-du-secret.fr/.

The R&D Survey uses the Frascati Manual from the OECD to define R&D activities. In particular, *R&D* is defined as planned, creative work aimed at discovering new knowledge, or developing new or significantly improved goods and services. It is distinguishable from other activities by the presence of a noticeable element of novelty and by the resolution of scientific or technological uncertainties. R&D includes basic research, aimed at acquiring new knowledge, without any specific immediate commercial applications or uses; applied research, aimed at solving a specific problem or meeting a specific commercial objective; and experimental development, consisting in the systematic use of research and practical experience to produce new or significantly improved goods, services, or processes. *Product Innovation* is defined as a new or significantly improved good or service with respect to its capabilities, user-friendliness, components or sub-systems. *Process innovation* is the implementation of a new or significantly improved production process, distribution method, or supporting activity. *Researchers* are professionals engaged in the conception or creation of new knowledge, products, processes, methods and systems, and in the management of the projects concerned. *Technicians* are people whose main tasks require technical knowledge and experience in one or more scientific or technical fields.

Industry-level trade data

We employ UN Comtrade data to construct our measure of import penetration of Chinese products into France and other developed economies. This dataset reports six-digit product level information on all bilateral exports and imports between country pairs. We aggregate from six-digit product level in SITC revision 3 to four-digit NACE revision 2 using the concordance table produced by the World Integrated Trade Solution from the World Bank (https://wits.worldbank.org/product concordance.html) and the Reference and Management of Nomenclatures (RAMON) produced by Eurostat (http://ec.europa.eu/eurostat/ramon). Often several SITC codes are matched to one

NACE code. Hence, we obtained the measure for import penetration for each NACE industry as the weighted average of each SITC industry mapping into it, where the weights are given by the import share of each SITC industry.

To obtain real values, we employ the Personal Consumption Expenditures index produced by FRED (https://fred.stlouisfed.org/series/PCE), as in Autor, Dorn, Hanson, Pisano, and Shu (2016). We employ the Gross Domestic Output growth for the European Union produced by the World Bank.