Does Import Competition Reduce Domestic Innovation and Productivity? Evidence from the China Shock and Firm-level Data on Canadian Manufacturing

Myeongwan Kim[1]
Centre for the Study of Living Standards

Abstract

A key economic issue in Canada is the declining business research and development and slowdown in the total factor productivity (TFP) growth in manufacturing since the early 2000s. To deepen our understanding of this phenomenon, we focus on the increasing Chinese import share in the total domestic absorption in Canadian manufacturing since the early 2000s, which appears to be driven by positive supply shocks within Chinese manufacturing. Based on firm-level data in Canadian manufacturing, we find that rising Chinese import competition led to declines in R&D expenditure and TFP growth within firms but reallocated employment towards more productive firms and induced less productive firms to exit. The negative within-effects were pronounced for firms that were initially smaller, less profitable, and less productive. At the aggregate level, the positive reallocation effects on TFP more than offset the negative within-effect. We estimate that, had there been no increase in Chinese import competition between 2005 and 2010, TFP in Canadian manufacturing would have declined by 1.26 per cent per year instead of the actual 1.09 per cent per year over this period.

A key economic issue in Canada is the declining Business Enterprise Research and Development (BERD) — a key input to innovation — since the early 2000s. Espe-

1 The author is currently a Ph.D. student in the Department of Economics at the University of Toronto. This article is an abridged version of Kim (2019), which was written when the author was an Economist at the Centre for the Study of Living Standards. An earlier version was presented at the CSLS session on "The Impact of China on the Canadian Economy" at the annual meeting of the Canadian Economic Association held in Banff, Canada, June 1, 2019. The author thanks the participants at the CEA session and Alex Murray (Finance Canada) for discussion. The author also thanks Andrew Sharpe (CSLS), Bert Waslander, Simon Lapointe (CSLS) and Jianmin Tang (ISED), and two anonymous referees for useful comments. Email: myeongwan.kim@mail.utoronto.ca.

cially, in manufacturing, BERD expenditure started to decline after 2000 both in levels and as a share of sales. Accompanying this, total factor productivity (TFP) growth in manufacturing slowed after 2000.

Since the early 2000s, advanced economies including Canada have experienced a rapid increase in imports from China. A large literature has documented that increasing trade with low-wage countries have an impact on domestic innovation although the evidence is mixed for the direction of the impact.[2] In this article, we assess whether declining R&D and productivity performance in Canadian manufacturing can be linked to rising Chinese import competition in final product markets. As the competition in the domestic product market rises, surviving firms are likely to adjust their innovative effort as their rents after innovation relative to rents before innovation are affected. Moreover, less productive firms may exit and resources could be allocated towards more productive surviving firms.

There are some close antecedents to our study but their empirical evidence is mixed. Bloom, Draca, and Van Reenen (2016) use firm-level data from European countries to estimate the effect of increasing Chinese import competition on four indicators for technical change: patents, information technology intensity, R&D investment, and TFP growth. They find empirical evidence that increasing Chinese import competition had led to an increase in all four measures of technical change within firms and also reallocated employment towards more technologically-advanced firms.[3]

Autor, Dorn, Hanson, Pisano, and Shu (2017) find conflicting evidence using firm-level data for the United States. They find that, in response to increasing Chinese competition, firms scaled back their patent activity and R&D investment. Gong and Xu (2017) also studies the effect of rising Chinese import competition on R&D expenditure of the U.S. firms but focus on the reallocation effect. They find that rising Chinese competition reallocated R&D expenditure towards more productive and profitable firms but find no evidence of an impact on R&D at the aggregate level. Using survey data,[4] Keung, Li, and Yang (2016) find that Canadian manufacturing firms scaled back their effort in process innovation relatively more than product innovation in response to rising Chinese import competition between 1999 and 2005.

Those conflicting empirical results are in line with the overall ambiguity in theoretical implications for the effect of rising competition on innovation. There are multiple theories underlying the relationship between competition and innovation. For example, "trapped inputs" for production imply that increased Chinese import competition fosters innovation as it reduces the relative profitability of low-tech products (e.g. Bloom, Romer, Terry and Van

2 See Shu and Steinwender (2018) for a comprehensive review of the studies on the impact of trade liberalization on innovation and productivity.

3 They also find that technologically-advanced firms are more likely to survive for a given increase in Chinese import competition than low-tech firms.

4 The Workplace and Employee Survey (WES) by Statistics Canada.

Reenen, 2010). Also, an increasing market size for Canadian firms due to expanding trade opportunity with China may encourage innovation as firms can spread the fixed costs of innovation over the larger market (e.g. Krugman, 1980; Acemoglu, 2008).

In contrast, in a standard oligopoly model, increased competition in product markets is likely to reduce incentives to innovate as profits decline (e.g. Dasgupta and Stiglitz, 1980). If we take into account differential degrees of competition faced by firms, the relationship between innovation and competition exhibits an inverted U-shape (e.g. Aghion *et al.*, 2005). Schmidt (1997) shows that increasing competition increases managerial effort to increase profit (so likely to increase innovation) but when competition becomes too intense, managerial effort may decline eventually.[5]

As emphasized in Melitz (2003) and Bloom *et al.* (2016), it is also important to consider an economy-wide technical change that occurs through the reallocation of resources. In theory, if we maintain the menu of products fixed in the economy, then increasing trade with low-wage countries like China would results in shrinking low-tech firms and growing high-tech firms (where Canada has comparative advantages). The opposite would occur in China.

Our study adds to the literature in two ways. First, to our knowledge, there is no empirical study that uses Canadian firm-level data to explore the impact of rising Chinese import competition on R&D which is a representative indicator of innovation activities or on the overall productivity performance in manufacturing. In this article, we carry out a comprehensive assessment of trade-induced change in R&D and TFP within manufacturing firms. Especially, our data capture a broad scope of R&D expenditure covering in-house R&D, R&D contracted out, and the use of R&D performed by third-parties on a non-exclusive basis. We also explore whether technical changes occurring *between* firms are important in Canada by analyzing the effect on employment and survival of manufacturing firms, focusing on the differential effects stemming from different initial technology levels of firms.

Second, most empirical studies focus on very large firms (e.g. public firms in Compustat) or firms with patents among those large firms. Large firms or firms with successful innovation outcomes (*i.e.*, patents) could have different initial conditions and hence, their response could be quite different than the majority of smaller firms in manufacturing or firms that perform R&D whose outcome does not necessarily get patented. In our study, we use administrative firm-level data covering all incorporated firms in Canadian manufacturing. Also, the database is linked to the tax data covering all firms that claimed R&D expenditure credits in Canada. Using this comprehensive database, we explore potential heterogeneity in firm-level responses to rising import competition, providing a better understanding of trade-induced change in

5 Also, domestic innovation could decline if domestic firms are deterred from entering export markets. For example, Baldwin, Dar-Brodeur, and Yan (2016) find that Canadian manufacturing firms that entered export markets are more likely to have invested in R&D before entry and to invest more in R&D after entry.

innovation and productivity. In particular, we assess the impact of rising import competition on R&D and TFP within firms by initial conditions of firms (e.g. initial size, profitability or mark-up, and productivity level).

We find that increasing Chinese import competition reduced R&D and TFP growth within firms but reallocated employment towards more productive firms and drove less productive firms out of the domestic market. The negative within-effects on R&D and TFP growth were pronounced in initially smaller, less profitable, and less productive firms.[6] It appears that, if survived, they scaled back their R&D investment but did not resort to other productivity-enhancing activities. Even if they did, they were not successful. R&D investment within initially larger, more profitable, and more productive firms was not affected by rising Chinese import competition. We find evidence that some larger and better-performing firms engaged in productivity-enhancing activities other than R&D when the Chinese presence increased in their product market, and hence their TFP improved. Very large firms (employees>500) do not appear to have adjusted their innovative effort to enhance their productivity.

Our results show that initially smaller and poorly-performing firms that survived experienced declining profit margins due to rising import competition while larger and their better-performing counterparts did not. A larger reduction in R&D and TFP may be explained by the shrinking room to finance R&D and other productivity-enhancing effort. Firms tend to finance innovation using internal cash flows as external financing would be costly in this case. Or in a different perspective, these firms are likely to have faced greater product market competition with technology gaps initially. So, if survived, a further increase in competition may have made additional innovation unprofitable for them. In other words, the basic Schumpeterian effect dominates for these firms, reducing more the post-innovation rents than the pre-innovation rents.

At the aggregate level, our estimates imply the increased share of imports from CHina explains about 7 per cent of the total decline of $1.36 billion (2007 CAD) in R&D expenditure in Canadian manufacturing between 2005 and 2010. Our productivity decomposition exercise indicates that had there been no increase in the share of Chinese imports in the total domestic absorption in manufacturing between 2005 and 2010, the aggregate TFP level in manufacturing would have declined by 1.26 per cent per year instead of the actual 1.09 per cent per year. This implies that the positive between- and exit-effects more than offset the negative within-effects.

The remainder of the article is organized as follows. The first section provides some motivating stylized facts about Chinese import competition, R&D expenditure, and productivity performance in Canadian manufacturing. Data sources are

6 For R&D, we also find the declines were larger within foreign-controlled firms and firms receiving regular tax credits for R&D expenditure, compared to domestically-controlled firms and firms receiving enhanced tax credits, respectively. Refer to Kim (2019) for details.

introduced in section two. Section three introduces our empirical models and identification strategy, which is followed by the results in section four and five. In section six, we contextualize our empirical findings by quantifying the role of rising Chinese import competition in driving the actual change in R&D investment and TFP growth in Canadian manufacturing. Section seven concludes.

Chinese Imports, R&D Expenditure, and TFP Growth in Canadian Manufacturing

Imports from low-wage countries have implications for technical change in developed economies.[7] During the 2000s, two of the top ten importers to Canada were low-wage countries: China and Mexico.[8] However, import penetration from China had been much more important in terms of both absolute levels and changes (Chart 1). The import penetration ratio for Mexico remained below 4.0 per cent for most of the 1990s and 2000s. It increased from 2.0 per cent in 2000 to 4.0 per cent in 2015. The import penetration ratio for China surpassed that for Mexico during the early 2000s when China joined WTO, reaching 8.9 per cent in 2015. It grew by 6.9 percentage points between 2000 and 2015.

According to the official data publicly available at Statistics Canada, between 1994 and 2000, the real BERD expenditure (covering only in-house R&D) in Canadian manufacturing increased rapidly. However, it started to decline when Chinese imports surged in the early 2000s (Chart 2). Our firm-level data on R&D only cover the 2000-2012 period, preventing us from comparing the pre- and post-take-off in Chinese imports in Canada. Nevertheless, we observe similar trends after 2000. The average annual growth rate in real R&D expenditure based on our firm-level data was -0.2 per cent in manufacturing for the 2000-2012 period.[9] The average annual growth rate was 4.1 per cent for the 2000-2005 period but fell to -3.2 per cent for the 2005-2012 period.[10] BERD expenditure fell in relative terms as well. Both the manufacturing share in total BERD expenditure in Canada and R&D intensity defined as BERD expenditure as a share of the total sales in manufacturing declined after 2000.[11]

Accompanying the declining R&D expenditure, TFP growth in manufacturing slowed after 2000. Chart 3 shows time series for TFP index based on the Canadian Productivity Account for Canadian man-

7 See, for example, Bartel *et al.* (2007); Freeman and Kleiner (2005); Bugamelli *et al.* (2008).

8 The top ten exporters to Canada were: United States, China, Mexico, Germany, Japan, South Korea, United Kingdom, Italy, France, and Taiwan.

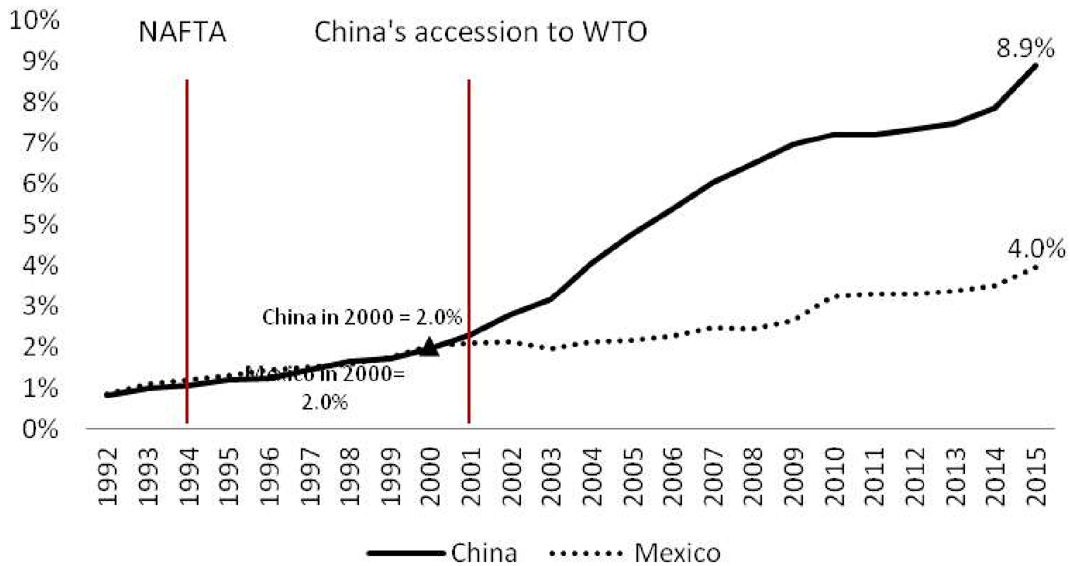
9 The average annual growth was 1.3 per cent in non-manufacturing during the same period.

10 A similar pattern is found in non-manufacturing: 5.9 per cent for the 2000-2005 period and -1.9 per cent for the 2005-2012 period.

11 See Kim, 2019:7 for details.

12 The Canadian Productivity Account data are publicly available at Statistics Canada. The CPA is constructed based on establishment-level data.

Chart 1: Import Penetration Ratio in Canada, Low-wage Countries: China and Mexico, Manufacturing, 1992-2015



Note: The import penetration ratio is defined as the ratio of imports to domestic absorption (total industry shipment less exports plus imports).
Source: Authors' calculation based on trade data base maintained by Innovation, Science, and Economic Development Canada and Statistics Canada Table 16-10-0047-01.

ufacturing.[12] TFP grew at a faster rate during the 1990s than during the 2000s. For instance, the annualized growth in TFP was 3.13 per cent over the 1992-2000 period. However, TFP declined at an annual rate of 1.09 per cent over the 2000-2009 period. After a rapid increase during the 1990s, TFP started to level off from the early 2000s. Then, it declined between 2006 and 2009 before it started to recover after 2009.[13]

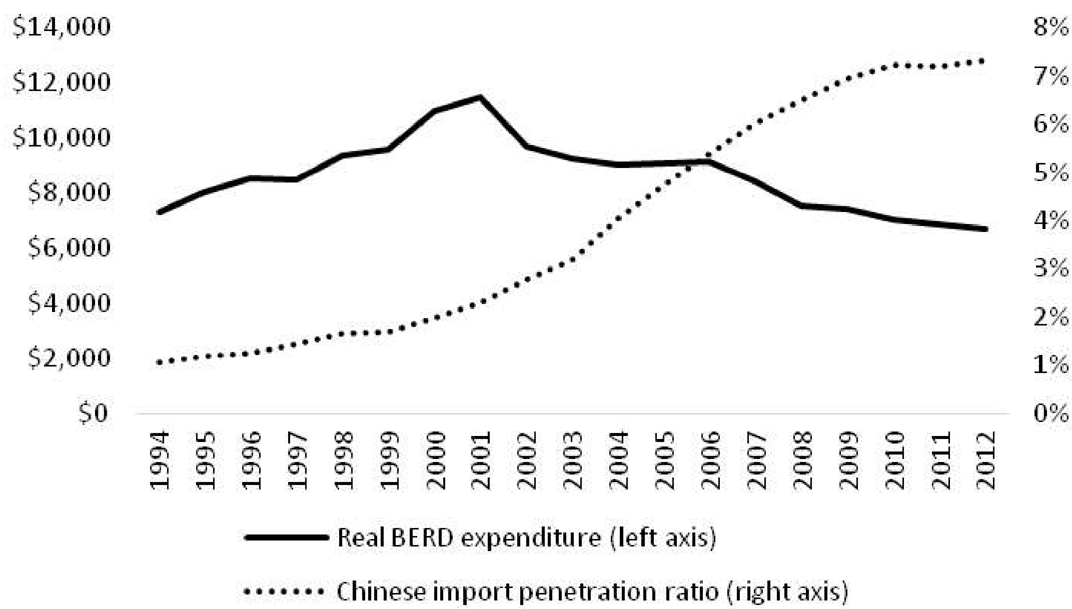
Data

The main data source for our analysis is corporate income tax (T2) files linked to Statistics Canada's Longitudinal Employment Analysis Program (LEAP) data file. The database includes information on firm-level output and conventional factors of production to estimate TFP. In order to have information on R&D expenditure for each firm, the database is linked to the Canada Revenue Agency (CRA) form T661 filed by firms to claim their tax credits for expenditure on scientific research and experimental development (SRED) — hence, T2-LEAP-SRED. We provide more detailed information on T2-LEAP-SRED in Kim (2019).

We use the Trade Data Online by Innovation, Science, and Economics Devel-

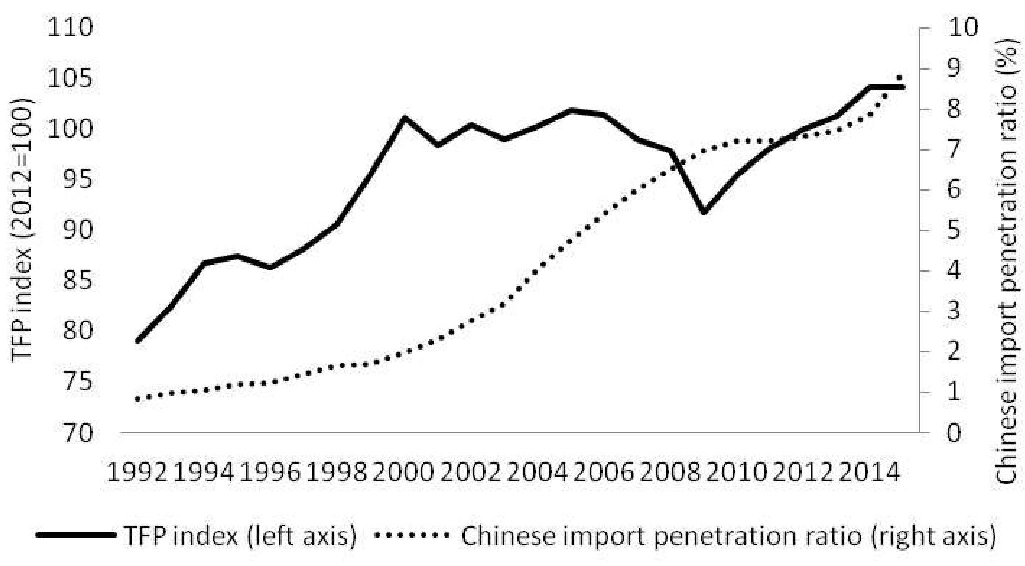
13 Again, due to the limited information in our firm-level data, we can examine TFP only for the 2000-2012 period. We observe the TFP level in manufacturing based on T2-LEAP-SRED exhibits a pattern similar to that found in the CPA data for the 2000-2012 period.

Chart 2: Real R&D Investment in Canadian Manufacturing, Millions of 2007 CAD, 1994-2012



Note: We use the GDP deflator for R&D expenditure.
Source: Author's calculations based on Statistics Canada Table 27-10-0002-01, 27-01-0273-01, 16-10-0047-01, and Trade Data Online maintained by Innovation, Science, and Economic Development Canada.

Chart 3: TFP Index (2012=100) and Chinese Import Penetration Ratio in Canadian Manufacturing, 1992-2015



Source: Authors' calculation based Statistics Canada Table 36-10-0208-01 and on trade data base maintained by Innovation, Science, and Economic Development Canada and Statistics Canada Table 16-10-0047-01.

opment Canada and the UN Comtrade database to construct our measure of Chinese import competition for Canada and other advanced economies required for our identification strategy. The UN Comtrade database follows the Harmonized Item Description and Coding System (HS). We therefore implement a mapping between HS and NAICS following the algorithm developed by Pierce and Schott (2012). Refer to Murray (2017) and Kim (2018a, b) for more detailed description of the data.

Our sample period covers 2000-2012. The sample for R&D analysis consists of firms that performed or purchased R&D at least once between 2000 and 2012. For the analysis on TFP, the sample consists of firms that have non-missing values for all the variables required to estimate firm-level TFP.

Empirical Models and Identification Strategy

Technical changes within firms

Our empirical models assess the effect of Chinese import competition on technical change within firms in manufacturing. To do so, we analyze two indicators of technical change: R&D expenditure and TFP growth. Following Bloom *et al.* (2016), we estimate the following two equations:

$$\Delta \ln(R\&D)_{i,j,\tau} = \beta^{R\&D}\Delta IP_{j,\tau} + \gamma X_{i,j,\tau} + \alpha_\tau + \varepsilon_{i,j,\tau} \quad (1)$$

$$\Delta \ln(TFP)_{i,j,\tau} = \beta^{TFP}\Delta IP_{j,\tau} + \gamma X_{i,j,\tau} + \alpha_\tau + \varepsilon_{i,j,\tau} \quad (2)$$

where i denotes firms and j denotes sectors in manufacturing. Δ represents the operator for long differences (e.g. 5-year long differences) for a given variable. $X_{i,j,\tau}$ includes all other controls for non-trade related factors specific to firms and to sectors in manufacturing. α_τ represents period fixed effects. $\Delta IP_{j,\tau}$ is a measure of Chinese import penetration which is constructed as follows:

$$\Delta IP_{j,\tau} \equiv \frac{\Delta M_{j,\tau}^{China}}{Y_{j,\tau_0} + M_{j,\tau_0} - E_{j,\tau_0}} \quad (3)$$

where the numerator $\Delta M_{j,\tau}^{China}$ denotes the change in import in sector j from China over period τ. The denominator $(Y_{j,\tau_0} + M_{j,\tau_0} - E_{j,\tau_0})$ represents the domestic absorption in sector j in the initial period τ_0.

Technical changes between firms: reallocation of employment and survival

To assess between-firm effects of Chinese import competition, we estimate the following equation:

$$\Delta \ln(N)_{i,j,\tau} = \beta^N \Delta IP_{j,\tau} + \lambda^N \left(TECH_{i,j,\tau_0} * \Delta IP_{j,\tau}\right) + \varphi TECH_{i,j,\tau_0} + \gamma X_{i,j,\tau} + \alpha_\tau + \varepsilon_{i,j,\tau} \quad (4)$$

where N is a measure of employment. $TECH_{i,j,\tau_0}$ is a measure of technology level for firm i in sector j in the initial period τ_0.

Increasing import competition from China could affect the probability of survival. Thus, we estimate the effect of trade on survival of firms in our data as follows:

$$S_{i,j,\tau} = \beta^S \Delta IP_{j,\tau} + \lambda^S \left(TECH_{i,j,\tau_0} * \Delta IP_{j,\tau}\right) + \varphi TECH_{i,j,\tau_0} + \gamma X_{i,j,\tau} + \alpha_\tau + \varepsilon_{i,j,\tau} \quad (5)$$

where $S_{i,j,\tau} = 1$ if firm i in sector j survives over period τ and zero otherwise. Equation (5) is estimated on a cohort of firms that exist in the sample in a given base period.[14] We follow those firms over period τ to assess their value for $S_{i,j,\tau}$.

The main parameter of interest is λ in equations 4 and 5 as it reflects whether the size of the effect of Chinese import competition on employment growth or survival varies with the initial level of technology. If low-tech firms are affected more negatively by China then we expect $\lambda > 0$. In other words, $\lambda > 0$ indicates that employment tends to shift towards high-tech firms and low-tech firms tend to exit in response to increasing Chinese import competition.

Identification strategy

To identify shocks exogenously driven by rising Chinese exporting capacity, we exploit the fact that growth in Chinese exports to developed economies like Canada since the early 2000s were mostly driven by factors internal to China (*e.g.* urbanization, opening to foreign investment, rising competitiveness in manufacturing, and accession to the WTO) rather than by positive demand shocks within developed economies.

We capture the common within-industry factors of rising Chinese exporting capacity, which stemmed from rising Chinese comparative advantage in manufacturing and lower trade costs due to factors internal to China. Thus, following Autor, Dorn, and Hanson (2013), we instrument for changes in the Chinese share of the domestic absorption in Canada using the changes in Chinese imports in the following eight advanced economies: Australia, Denmark, Finland, Germany, Japan, New Zealand, Spain and Switzerland.[15]

The first-stage regression is the following:

$$\Delta IP_{j,\tau} = \delta \Delta IPE_{j,\tau} + \widetilde{\gamma} X_{j,\tau} + \widetilde{\alpha_\tau} + \widetilde{\eta_j} + \mu_{j,\tau} \quad (6)$$

where $\Delta IPE_{j,\tau}$ represents changes in the Chinese import penetration ratio in the eight comparison countries.

The above strategy has the following key identifying assumptions: 1.) industry-specific shocks are uncorrelated across Canada and the eight countries; and 2.) there are no strong increasing returns to scale in Chinese manufacturing such that Canadian shocks increase efficiency within relevant Chinese manufacturing industries and lead them to export more to the eight other economies. The former may be a

14 T2-LEAP-SRED is adjusted for mergers and acquisitions and legal restructuring. Therefore, we can treat disappearance of a firm as true exit.

15 We exclude the United States because its economy is highly integrated with Canada and is likely to have experienced similar demand shocks.

concern in our analysis. We are particularly concerned with the possibility of correlated shocks related to the innovation in the use of ICT technologies, which were observed in most of the advanced economies around the world, increasing demand for ICT-related goods from China.[16] The second is not of serious concern since Canada is a small open economy. Shocks within 4-digit NAICS in Canada are not likely to have a substantial impact on the efficiency within relevant Chinese industries.

It appears that the change in trade exposure to China in the eight advanced economies has good predictive power for the change in Canada. In our regression analysis, we use 5-year sub-periods covering the 2000-2012 period. R-squared varies across the 5-year sub-periods but is greater than 80 per cent in most cases — approximately 80 per cent of the variation in the import penetration ratio in Canada is presumably driven by exogenous supply shocks.

Descriptive Statistics

Summary statistics for some key variables used in our analysis by initial employment size are reported in Table A1 and A2 in the Appendix. Firms in the R&D sample (Table A1) tend to be larger in terms of employment and have a larger increase in their productivity over time, compared to the firms in the TFP sample (Table A2) which is a larger sample. Both in the R&D and the TFP sample, we find that the initial level of profitability and the initial productivity level were lower for smaller firms than for larger firms. In other words, firms with initially smaller employment are more likely to operate in more competitive markets with technology gaps in the initial period.

Both in theoretical and empirical works, it is suggested that the initial level of profitability (or product market competition) and productivity of a firm have important implications for the firm's innovative effort in response to an increase in competition.[17] It is observed that, on average, initially smaller firms experienced a larger increase in the Chinese import competition; a larger decrease in profitability; and a smaller increase in their productivity level.

Regression Results: R&D Equation

Baseline results

In Table 1, we report the regression results for estimating our R&D equation. As in Bloom *et al.* (2016), we use overlapping long-differenced samples of a 5-year period (*i.e.*, 2000-2005; 2001-2006; 2002-2007; and so on) to maximize the number of observations in our sample.[18] Using first-

16 Some robustness checks reveal that our result is not particularly sensitive to these industries. Refer to Kim (2019:18) for details.

17 See, for example, Aghion *et al.* (2005) and Autor *et al.* (2017).

18 Similar results are found when we use different lengths of overlapping sub-periods (e.g. 3-year; 6-year). We also tried using one or two long-differenced sub-periods (e.g. 2000-2007 or 2000-2005 and 2005-2010). Again, we found that the coefficients for ΔIP remain very similar to the ones reported in Table 1.

differenced samples (*i.e.*, change from one year to another) may lead to attenuation bias. It may not capture any meaningful adjustment in the innovation effort in response to increasing Chinese import competition, which is likely to occur over the medium- or long-term.

In columns 1 and 2, we estimate the same R&D equation but using different estimation methods. The OLS estimate in column 1 indicates that there is no significant effect of the China shock on the R&D expenditure growth within manufacturing firms. Using exogenously-driven variation in ΔIP, we find a negative and statistically significant effect on R&D in column 2.[19]

However, there could be unobserved industry-specific shocks that are correlated with both R&D investment and the Chinese import penetration ratio. Hence, as our first robustness check, in column 3, we report the results for controlling for industry trends in our sample. Here, we include 3-digit NAICS industry dummies.[20] We continue to obtain a negative and statistically significant coefficient on ΔIP although the coefficient is slightly smaller due potentially to attenuation bias.

In column 4, we include different firm-level controls to account for potential confounding factors. First, we include R&D intensity (R&D stock divided by value added) and tangible capital-to-value added ratio, both measured in the initial period (e.g. the 2000 value for the 2000-2005 subperiod). Second, we include the log of wage per worker averaged over our sample period.[21] Similar to Bernard *et al.* (2006) and Bloom *et al.* (2016), we use these variables as proxies for the initial technology level. Third, we include dummies for foreign-controlled firms and for the enhanced SR&ED tax credit recipients.[22] The coefficient for ΔIP remains negative and statistically significant with these control variables.

Explaining the Negative Effect

It is possible that increasing Chinese imports leads to declining R&D expenditure by creating competitive pressure on firms, reducing their expected rents after R&D relative to rents before R&D. However, with differential degrees of competition initially faced by firms, the impact of increasing competition on R&D investment may not be uniform across all firms (e.g. Aghion *et al.*, 2005).

Firms with significant market power (e.g. larger firms) may be less responsive in adjusting their R&D effort. Their rents would

19 We experiment with an alternative instrument as proposed in Bloom *et al.* (2016), which is similar in nature to the instrument adopted in Card (2001) by using as instruments the Chinese import penetration ratio measured in the initial period as instrument for its subsequent increases. We still find a negative and statistically significant coefficient. Refer to Kim (2019:17) for details.

20 We also allow the time trends to differ by 3-digit NAICS industry.

21 Wage is defined as payroll divided by average labour unit. Since the average labour unit is defined as the total payroll divided by average annual wage of a typical worker in the firm's 4-digit NAICS industry, province and firm size class, wage would be defined not at the firm-level but at the 4-digit NAICS industry x province x firm size class level.

22 We find that the control variables are jointly significant.

Table 1: R&D Equation, Manufacturing, 2000-2012

	1: OLS	2: 2SLS	3: Industry fixed effects	4: Various firm-level controls
ΔIP	-0.461	-1.027***	-0.857*	-0.805**
	(0.285)	(0.395)	0.448)	(0.398)
No. firm x period	118,427	116,683	116,683	101,485
No. firms	17,314	17,066	17,066	15,529
Estimation	OLS	2SLS	2SLS	2SLS

Note: The dependent variable is Δln(R&D expenditure). All columns include period fixed effects. Standard errors are in parenthesis. Δ denotes a 5-year difference. The number of observations is smaller for the columns based on our IV approach than column 1 since there is no HS-NAICS mapping for NAICS 3328 (see Kim (2019) for details). For column 4, some observations have missing values for some of the control variables we consider. Hence, the number of observations is slightly smaller than in the other columns. *** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$.

not be significantly affected by rising competition as it would be difficult for laggards (*i.e.*, Chinese manufacturers) to overtake leaders (*i.e.* large Canadian manufacturers) or Chinese manufacturers may operate in different product markets. On the other hand, for firms already facing a high degree of competition with technology gaps (e.g. smaller firms), increasing competition may substantially hurt their profit margins, implying less room to finance innovation[23] and/or to capture rents after R&D. As a result, if such firms survived, they might have been more responsive in reducing their expenditure on R&D as competition rises.

To empirically examine this idea, we estimate the R&D equation in which we interact ΔIP with the size indicator to examine whether the coefficient differs by size group (in terms of the initial employment size).[24] Small firms tend to be not only less profitable (or operating in more competitive markets) but also less productive in the initial period (see Table A1 in the Appendix). In column 1 in Table 2, we find negative coefficients in all three size groups but the statistical evidence for medium and large firms is weak. It appears that only small firms were negatively affected.[25]

It is likely that small firms' profit margins were negatively affected by rising import competition, leading them to reduce R&D expenditure. We estimate the impact of increasing Chinese imports on the profitability of firms performing R&D in manufacturing. Given the data availability in the T2-LEAP-SRED database, we define profitability as profit divided by sales where we use net income or loss before tax as profit.

In column 2 in Table 2, our 2SLS estimate indicates that increasing Chinese import competition indeed reduces the profitability of firms. A further analysis by size in column 3 indicates that only small firms were negatively affected by increasing import competition from China. We find

23 For example, Hall (1992) finds a positive elasticity of R&D investment with respect to cash flow controlling for other factors and that debt is not a preferred form of financing R&D. Using cash flow is likely to be the main avenue to finance R&D since external financing may be costly.

24 We define the three size groups based on the average labour unit (ALU) observed in the initial period: small ($ALU < 100$); medium ($100 \leq ALU < 500$); and large ($500 \leq$).

25 We also estimated the equation based on two size groups by aggregating medium-sized and large firms. However, we found the same qualitative results.

Table 2: R&D and Profit Equation, 2SLS, Manufacturing, 2000-2012

	Δ ln(R&Dinvestment)	ΔProfitability	
	1	2	3
ΔIP	—	-0.057***	—
		(0.018)	
$\Delta IP \times$ initially small	-1.299***	—	-0.068***
	(0.468)		(0.022)
$\Delta IP \times$ initially medium − sized	-1.056	—	-0.014
	(0.950)		(0.031)
$\Delta IP \times$ initially large	-0.991	—	-0.013
	(0.836)		(0.025)
No. observations (firm x period)	116,683	103,816	103,816
No. firms	17,066	15,956	15,956

Note: Period fixed effects are included in all columns. Standard errors are in parenthesis. Δ denotes a 5-year difference. Initial employment size is measured as the average labour unit (ALU) observed in the initial year (*e.g.*, ALU in 2000 for the 2000-2005 sub-period). We define the three size groups based on the average labour unit (ALU) observed in the initial period: small ($ALU < 100$); medium ($100 \leq ALU < 500$); and large ($500 \leq$). Profitability is defined as profit/revenue where we use net income or loss before tax as a proxy for profit.
*** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$.

no evidence that the profitability of larger firms is affected by Chinese imports. This implies that rising Chinese import competition translated into increased competitive pressure (*i.e.*, decreasing mark-ups) mostly for small firms.[26]

We carry out some robustness checks. We divide observations into three groups groups by their profitability level observed in the initial year and by the initial TFP level (measured as relative to the industry average), respectively. We indeed find that a higher initial level of competition faced by firms or a lower initial level of productivity is associated with a larger negative effect of rising Chinese competition on their R&D expenditure.[27]

In summary, smaller firms or firms initially operating in more competitive markets with technology gaps appear to be the ones most directly affected by increasing Chinese import competition. Declining profit margins indicates less room to finance R&D and/or lower expected post-innovation rents implying it is optimal for them to scale down their expenditure on R&D if they survived. In contrast, profit margins of larger firms or firms initially operating in less competitive markets with relatively high levels of technology were not affected much by increasing Chinese competition, and hence, they made less or no adjustment in their R&D investment. These larger firms may have been incum-

26 These results (both R&D expenditure and profit margins by size) are not driven by very small firm or "micro-firms" in our sample. We tried dropping increasingly larger "micro-firms" (e.g. firms with ALU<2, ALU<3, ALU<4 and so on) but the significance level and the sign of the coefficients remained the same. Also, the magnitude of the coefficients did not change significantly. We also tried including industry fixed effects since small firms tend to be in industries with large increases in Chinese import penetration ratio during our sample period (see Table A1 in the Appendix). Even with the industry fixed effects, we still found that only small firms experienced declines in their R&D expenditure and profit margins due to rising Chinese import competition.

27 Refer to Kim (2019) for the results.

bents competing with each other with similar levels of technology within their product markets but faced not much competition having small or no incentives to innovate. Or if there were laggards they would quickly catch up the leaders but once they have caught up they would have been slow to innovate further given low competition. At equilibrium, there would be a larger fraction of neck-and-neck competing incumbents with not much innovation. Such initial state (or the competitiveness of the market for these firms) were not affected much when Chinese manufacturers entered the Canadian market. As a results, the incumbent firms maintained the status quo which we observe in our data: no effect on their profitability and hence, not much adjustment in their innovative effort in response to rising Chinese competition.[28]

Some firms may have undergone industry-switching or reorganization such that they shift away from the physical production of goods towards "neuro-manufacturing" where they focus more on the design, engineering, and marketing of their goods or towards producing related professional services.[29] This may have spurred additional R&D investment within these firms but this would be observed in our data only if their primary industry code did not change to non-manufacturing due to the shift of their economic activity.

Our results imply that firms accounting for a large share of the total R&D expenditure are not likely to reduce R&D in response to increasing Chinese import competition. A small number of medium-sized and large firms account for a disproportionately large share in the total R&D expenditure in Canadian manufacturing. These larger firms account for 14 per cent of the total observations but about 77 per cent of the total R&D expenditure in manufacturing.[30] Hence, the cumulative partial impact of the China shock on the aggregate R&D expenditure in manufacturing may be limited.

Regression Results: TFP, Employment, and Survival Equation

In order to assess the impact of China on the technical change in Canadian manufacturing in a broader perspective, we estimate its impact on TFP within Canadian manufacturing firms and on the employment and the survival of firms to assess potential reallocation effects. Using the estimates from these analyses, we carry out a TFP decomposition in section six to estimate the share of the aggregate TFP change in Canadian manufacturing induced

28 This is more likely to be the case for large firms or firms operating in a concentrated market. In the following section, we show medium-sized firms appear to have resorted to other types of productivity-enhancing activities while not scaling back their R&D in response to rising import competition.

29 Some U.S. examples are Apple and IBM. Apple outsources its production to China and focuses more on product development and producing related services in the United States. IBM sold their ThinkPad business line to Lenovo which produces ThinkPad laptops in China. IBM now produces professional services related to data management and system design.

30 Medium firms (large firms) account for 11 (3) per cent of the total observations but 23 (62) per cent of the total R&D expenditure in manufacturing on average over the 2000-2012 period.

by increasing Chinese import competition.

Within-effect: TFP Equation

For estimation of firm-level TFP, we experimented with OLS and GMM for a dynamic panel data model introduced in Blundell and Bond (1998) (*i.e.*, system-GMM). We estimate a firm-level Cobb-Douglas production function by three-digit NAICS industry in manufacturing and use the estimated coefficients for inputs to retrieve estimates of firm-level TFP.[31] In this section, we report the results based on OLS as we could not find a completely satisfactory specification for GMM. We carried out all our analyses using firm-level TFP estimated with system-GMM and found that the key results in the article did not change. In Kim (2019), we discuss in more detail different estimation strategies including semi-parametric approaches and our reasons for adopting OLS to estimate TFP in our study.

Table 3 reports the results from estimating the TFP equation as described in section three. As with R&D, we find that increasing Chinese import competition reduces the TFP growth within manufacturing firms as indicated by the negative coefficient in column 1. The negative effect is robust to including industry fixed effects or including the firm-level controls introduced in column 4 in Table 1 or using the alternative instrument (see footnote 23).

The negative within-effect reported in column 1 can be related to our findings for R&D: in response to rising import competition, initially smaller and poorly-performing firms experienced declining profit margins and scaled back their R&D effort. If similar firms (not necessarily R&D performers) that survived in manufacturing scaled back their expenditure on R&D (if had any) and/or did not allocate their resources to additional productivity-enhancing effort (e.g. better management or inventory controls), then their TFP growth would decline.

As is the case for the R&D sample, we find a negative effect of increasing Chinese import competition on profitability for the TFP sample (column 3 and 4). Importantly, we find that only small firms experienced a negative effect on their profitability while larger firms did not. We estimate the TFP equation by interacting ΔIP with the size indicator (defined based on ALU observed in the initial period) in column 2 in Table 3. Again, only small firms experienced a negative effect on TFP growth.[32] Medium-sized firms actually experienced productivity gain due to increasing Chinese import competition while we find no evidence that large firms' TFP growth was affected.

Medium-sized firms may have focused on other productivity-enhancing activities

31 We also estimated a production function by two- and four-digit NAICS industry and carried out all the analyses. We found that the qualitative results remained the same.

32 As is the case in our R&D analysis by size, these results are not driven by very small firm or "micro-firms". We carried out the same sensitivity test as described in fn 30. Also, small firms tend to be in industries with large increases in the Chinese import penetration ratio (see Table A2 in the Appendix). We tried including industry fixed effects and still found that only small firms' TFP growth and profit margins were negatively affected.

Table 3: **TFP and Profit Equation, TFP Sample, 2SLS, Manufacturing, 2000-2012**

	Δ ln(TFP)		ΔProfitability	
	1	2	3	4
ΔIP	-0.137***	—	-0.012***	—
	(0.023)		(0.004)	
$\Delta IP \times$ initially small	—	-0.164***	—	-0.015***
		(0.024)		(0.004)
$\Delta IP \times$ initially medium − sized	—	0.140*	—	0.018
		(0.081)		(0.018)
$\Delta IP \times$ initially large	—	0.063	—	0.003
		(0.111)		(0.012)
No. observations (firm x period)	241,054	241,054	223,886	223,886
No. firms	43,331	43,331	41,984	41,984

Note: Period fixed effects are included in all columns. Standard errors are in parenthesis. Δ denotes a 5-year difference. Initial employment size is measured as the average labour unit (ALU) observed in the initial year (*e.g.*, ALU in 2000 for the 2000-2005 sub-period). We define the three size groups based on the average labour unit (ALU) observed in the initial period: small ($ALU < 100$); medium ($100 \leq ALU < 500$); and large ($500 \leq$). Profitability is defined as profit/revenue where we use net income or loss before tax as a proxy for profit.
*** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$.

(e.g. better management practices or inventory controls) while not scaling back their R&D investment (if they have invested in R&D) to remain competitive in the market. In contrast, large firms' effort to enhance productivity, if any, did not seem to have much effect on its TFP growth.

We also estimate the TFP equation splitting the observations into two categories (below and above the mean) by the initial profitability and productivity level , and find that the negative effect on TFP growth is mainly on less profitable and less productive firms. Also, we find the same qualitative results for the within-effect on TFP for the R&D sample. Refer to the Kim (2019) for the discussion and the results.

Between-effect: Employment and Survival Equation

The effect of increasing Chinese imports on the overall TFP in Canadian manufacturing cannot be fully assessed with the within-effect. The aggregate TFP change also includes the change driven by the reallocation of resources. That is, increasing Chinese import competition may have reallocated employment towards more productive firms or induced less productive firms to exit. These reallocation effects could be significant in driving the aggregate change in the TFP level in manufacturing.

In this section, we report the results from estimating the effect of increasing Chinese import competition on the employment growth and the survival of firms in manufacturing, particularly focusing on differential effects stemming from different initial technology levels of firms. We would like to study whether more technologically advanced firms are less likely to reduce employment and more likely to survive in response to increasing Chinese competition in the domestic market.

In Panel A of Table 4, we estimate the effect of China on the log change in employment but allow the effect to differ by the initial technology level by interacting

Table 4: Employment and Survival equation, 2SLS, Manufacturing

TECH variable:	R&D stock		TFP	
	Panel A: Employment equation			
Dependent: $\Delta\ln(employment)$	1	2	3	4
ΔIP	-0.136*	-1.253***	-0.289***	-0.294***
	(0.068)	(0.567)	(0.045)	(0.046)
$\Delta IP \times$ Initial TECH	—	0.105***	—	0.381***
		(0.053)		(0.094)
Initial TECH	0.026***	0.022***	0.327***	0.310***
	(0.004)	(0.004)	(0.008)	(0.008)
No. observations (firm x period)	38,153	38,153	165,825	165,825
No. firms	9,628	9,628	37,042	37,042
	Panel B: Survival equation			
Dependent: S	1	2	3	4
ΔIP	-0.027***	-0.165	-0.033***	-0.032***
	(0.012)	(0.125)	(0.011)	(0.011)
$\Delta IP \times$ Initial TECH	—	0.013	—	0.068***
		(0.011)		(0.021)
Initial TECH	-0.003*	-0.004*	0.048***	0.043***
	(0.002)	(0.006)	(0.005)	(0.004)
No. firms	6,937	6,937	32,861	32,861

Note: Period fixed effects are included in all columns. Standard errors are in parentheses. Δ denotes a 5-year difference. The dependent variable in Panel A is the log change in employment. The dependent variable in Panel B is S which equals one if a given firm survived the entire 2002-2007 period and zero otherwise. We use the average R&D stock and TFP level (measured as relative to the 3-digit NAICS industry average) observed in the initial and the two years prior to the initial year to mitigate potential measurement errors (*e.g.*, average over the 2000-2002 period for the 2002-2007 period). Hence, the sample period is 2002-2012 for Panel A and 2002-2007 for Panel B. R&D stock is divided by employment. Similar results are found when we use R&D stock divided by sales. Both technology variables enter the equation in logs.
*** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$.

ΔIP with the initial technology level. We use two proxies for the technology level: R&D capital stock and the TFP level (measured as relative to the 3-digit NAICS industry average). We find that increasing Chinese import competition is associated with a lower employment growth. More importantly, the negative effect of increasing Chinese import competition on the employment growth is smaller the higher the initial technology level. This is shown as the positive and statistically significant coefficients on the interaction terms (column 2 and 4). These results indicate that high tech firms may have been "shielded" from the negative effect of increasing Chinese imports on employment.

Next, we estimate the survival equation. For the survival analysis, we focus on a cohort of firms that was alive in a given initial year. We model the probability of their survival following these firms for five years. Our sample period in this analysis is 2002-2007 since we use as a measure of initial technology level the average R&D stock or the average TFP level measured based on the initial and the two years prior to the initial year to mitigate potential measurement errors. We continue to base our analysis on a 5-year sub-period to be consistent with the other analyses in the article.

The results reported in Panel B of Table 4 indicate that firms in industries with larger increases in the Chinese import penetration ratios are less likely to survive (or more likely to exit). A one-percentage-point increase in the penetration ratio is associated with a decrease in the survival probability of 0.027 to 0.033 percentage points according to column 1, 3, and 4 in Panel B.[33] Again, we find that more technologically advanced firms (as proxied by the average TFP level) are "shielded" from the negative effect of increasing Chinese imports as indicated by the positive and statistically significant coefficient on the interaction terms in column 4.[34] When R&D stock is used to proxy the initial technology level (column 2), we find the coefficient on the interaction term is insignificant but positive.

Quantifying the Role of China

Using the results from our regressions, we contextualize the findings to provide a broad picture of the role of China in driving the technical change in Canadian manufacturing. We would like to ask: *for a given period, how much of the total change in real R&D investment and the TFP level in Canadian manufacturing can be explained by increasing Chinese import competition?*

R&D Expenditure

We calculate the predicted change in the aggregate R&D expenditure driven by increasing imports from China as follows:

$$\Delta \widehat{R\&D}_{\tau}^{China} = \sum_i \beta^{R\&D} * \widetilde{\Delta IP}_{j,\tau} * R\&D_{i,j,0} \quad (7)$$

where $\beta^{R\&D}$ is the marginal response of R&D expenditure growth with respect to an increase in Chinese import penetration ratio and $\widetilde{\Delta IP}_{j,\tau}$ is the exogenously-driven change in the Chinese import penetration ratio for manufacturing sector j over period τ. We estimate $\widetilde{\Delta IP}_{j,\tau}$ by discounting the actual $\Delta IP_{j,\tau}$ by the R-squared from the first stage regression. $R\&D_{i,j,0}$ is the actual level of R&D expenditure for firm i in sector j at the start of period τ.

Table 5 reports the change in real R&D expenditure induced by increasing Chinese import competition for the 2000-2005 and 2005-2010 period, respectively. The estimates are based on the size-specific coefficients from column 1 in Table 2.[35]

We estimate that had there been no increase in Chinese import competition, R&D expenditure would have increased by about 8 per cent more (*i.e.*, by $1,318 million instead of $1,220 million) between 2000

33 Note that the mean exit rate of this cohort is 6.1 per cent for the 2002-2007 period. Using the mean ΔIP and initial technology level, our estimates in column 4, for example, represent roughly 1.23 percentage-point-increase in the mean exit rate.

34 Our sample and the estimates imply that increasing Chinese imports decreased the exit rate of high tech firms and increased the exit rate of low tech firms. For example, based on the estimates from column 4 and the mean ΔIP and initial TFP level observed for the 2002-2007 period, the firms in the top 30 per cent of the initial TFP level distribution have a predicted mean exit rate of 2.4 per cent which is lower than their actual mean of 3.9 per cent while the firms in the bottom 30 per cent have a predicted mean exit rate much higher than their actual mean rate (13.2 per cent vs. 9.4 per cent).

35 We carried out the same calculations assuming only small firms adjusted their R&D in response to rising Chinese import competition. We found that the role of China in explaining the total change in R&D falls roughly by a half. We also tried using the aggregate coefficient from column 2 in Table 1. With this, in an increase in the role of China by roughly 80 per cent. The former is potentially a lower bound since we assume all medium-sized and large firms did not adjust their R&D. The latter is potentially an upper bound since we impose the larger aggregate coefficient (driven mainly by small firms) on all firms in our sample.

Table 5: Change in R&D Expenditure due to China, Manufacturing, Millions of 2007 CAD, 2000-2010

	2000-2005	2005-2010
(1) R&D expenditure in Year 1 of sub-period	5,670	7,060
(2) Actual change	1,220	-1,360
(3) Actual % change	21.5%	-19.3%
(4) Induced change in R&D due to China	-98	-89
(5) Counterfactual change in R&D (2 - 4)	1,318	-1,271
(6) Counterfactual % change (5/1)	23.2%	-18.0%

Note: Estimates are computed based on the coefficients reported in column 1 in Table 2. R&D expenditure includes only domestically performed R&D in manufacturing.

and 2005. This counterfactual translates into a growth rate of 23.2 per cent between 2000 and 2005, a 1.9 percentage-point-increase from the actual growth rate of 21.5 per cent. Between 2005 and 2010, R&D expenditure in manufacturing fell by $1,360 million CAD. Our estimates imply that China can explain about 6.5 per cent of the total decline for this period. This implies that if the Chinese import penetration ratio did not change between 2005 and 2010, R&D expenditure in manufacturing would have fallen by 18.0 per cent instead of 19.3 per cent.

TFP

To assess the role of increasing Chinese imports in driving the aggregate TFP in Canadian manufacturing, we carry out a standard productivity decomposition using the estimates from Equation (1), (2), (4), and (5) following a similar decomposition methodology introduced in Bailey, Hulten, and Campbell (1992), Foster, Haltiwanger, and Krizan (2000), and Bloom *et al.* (2016):

$$\begin{aligned}\Delta \mathrm{P}_t = &\sum_{i=1}^{N} s_{i,0}\left(p_{ijt}-p_{ij0}\right)\\ &+\sum_{i=1}^{N} p_{ij0}\left(s_{it}-s_{i0}\right)\\ &+\sum_{i=1}^{N}\left(s_{it}-s_{i0}\right)\left(p_{ijt}-p_{ij0}\right)\\ &-\sum_{i\in exit} s_{i0}^{exit}\left(p_{ij0}^{exit}-\overline{p}_{j0}\right)\\ &+\sum_{i\in entrant} s_{it}^{entrant}\left(p_{ijt}^{entrant}-\overline{p}_{jt}\right)\end{aligned} \tag{8}$$

where P_t denotes the aggregate TFP level at a given point in time t. $\Delta \mathrm{P}_t$ represents the aggregate change in TFP between time 0 and t. $s_{i,t}$ denotes the employment share of firm i at time t (*i.e.*, firm employment divided by total employment in manufacturing).[36] $\overline{p}_{jt}$ is the average TFP of all firms in sector j at time t. N is the total number of firms in manufacturing.

The first term in Equation (8) is the within-firm effect which is the change in TFP level holding employment shares constant. The second term is the between ef-

36 Output shares could be used as weights in TFP decomposition. We adopt labour shares as weights in our decomposition given our econometrics framework based on Bloom *et al.* (2016).

fect, the change in TFP level due to shifting employment from less productive firms to more productive firms holding the initial productivity level constant. The third term is the cross effect which is simply the correlation between the change in TFP level and the change in employment share within firms. The second last term is the exit effect which represents the change in TFP level due to firm exits. The last term represents the entry effect. The contribution of entrants and exitors depends on entering or exiting firms' p_i relative to the average p_i of the incumbents.

We explicitly model each term in Equation (8) (except for the entry effect). Following Bloom *et al.* (2016), we can re-write Equation (8) in terms of our estimates from Equation (2), (4), and (5). Using our estimates from TFP, employment, and survival equations, we have:

$$\begin{aligned}\Delta P_t^{China} = & \sum_{i=1}^{N} s_{i,0}\left(\beta^{TFP}\Delta IP_j\right) \\ & + \sum_{i=1}^{N} p_{ij0}\left({s_{it}}^{between} - s_{i0}\right) \\ & + \sum_{i=1}^{N}\left({s_{it}}^{between} - s_{i0}\right) \\ & \times \left(\beta^{TFP}\Delta IP_j\right) \\ & - \sum_{i\in exit} s_{i0}^{exit}\left(p_{ij0}^{exit} - \overline{p}_{j0}\right) \end{aligned} \quad (9)$$

where β^{TFP} is the coefficient from Equation (2). ${s_{it}}^{between}$ is the predicted share of employment for incumbent firms and s_{i0}^{exit} is the predicted share of employment in exiting firms as defined in the following.

$${s_{it}}^{between} = \frac{N_{i0}(1+\beta^N\Delta IP_j + \lambda^N\Delta IP_j p_{ij0})}{\sum_{i=1}^{N} N_{i0}(1+\beta^N\Delta IP_j + \lambda^N\Delta IP_j p_{ij0})} \quad (10)$$

where β^N and λ^N are the coefficients from Equation (4). N_{i0} is the employment level in firm i at time 0.

$${s_{i0}}^{exit} = \frac{N_{i0}(1-\beta^S\Delta IP_j - \lambda^S\Delta IP_j p_{ij0})}{\sum_{i=1}^{N} N_{i0}(1-\beta^S\Delta IP_j - \lambda^S\Delta IP_j p_{ij0})} \quad (11)$$

where β^S and λ^S are the coefficients from Equation (5).

Finally, we can compute the magnitude of each component in Equation (9) by computing the ratio $\frac{\Delta P_t^{China}}{\Delta P_t}$ where ΔP_t is the actual change in the aggregate TFP level in manufacturing over the period $0-t$.

We cannot directly quantify the entry effect at the firm-level as it is not possible to observe the technology level of a given firm before entry.[37] We can implicitly assess the magnitude of the entry effect by estimating an industry-level version of Equation (2) and compare its coefficient which presumably captures within-, between-, and entry effects with the corresponding firm-level coefficients. We estimate that the entry effect is potentially small (refer to Kim (2019:32)).

Table 6 reports the results from our productivity decomposition focusing on the

37 Note that it is not appropriate to use the technology level at the time they enter as it is likely to be endogenous.

Table 6: **Change in TFP due to China, Manufacturing, 2005-2010**

	As a % of the *decline* in the TFP level between 2005 and 2010
Within (-)	5.4%
Between (+)	-17.1%
Exit (+)	-3.9%
Cross (+)	0.0%
Total (+)	**-15.6%**

period 2005-2010.[38] Note that the magnitudes are presented as a share of the actual *decline* in the aggregate TFP level in manufacturing between 2005 and 2010. Hence, negative (positive) sign implies that increasing Chinese import competition has positively (negatively) affected the total change in the TFP level.

We find that the TFP level declined within manufacturing firms between 2005 and 2010, negatively affecting the aggregate TFP level in manufacturing.[39] We estimate that the within-effect driven by increasing Chinese import competition can explain roughly 5 per cent of the total decline in the TFP level in Canadian manufacturing. However, there were substantial gains in the aggregate TFP level through the reallocation of resources. In response to increasing Chinese import competition, employment shifted from less productive firms to more productive firms. Also, less productive firms exited the market although its impact on the overall TFP is relatively small. The reallocation effects (between plus exit) driven by increasing Chinese import competition more than offset the negative within-effect, resulting in a net positive effect on the aggregate TFP change between 2005 and 2010. That is, had there been no increase in Chinese import competition in Canada, the per cent change in the aggregate TFP level would have been -1.26 per cent per year instead of -1.09 per cent per year.[40] As is often the case in other empirical studies, the cross-effect is negligible.

Our estimates imply that the reallocation of resources appears to be the main channel through which rising import competition raised the overall productivity performance in Canadian manufacturing. The within effect is negative but potentially small since the effect was pronounced in

38 We also analyzed the 2000-2005 period and the qualitative results were the same — as is the case for the 2005-2010 period, the sum of the between- and exit-effect was positive and more than offset the negative within-effect. However, the impact of China was not economically significant. Also, the actual TFP growth between 2000 and 2005 was very small (e.g. 0.42 per cent based on the CPA data or 0.02 per cent based on the T2-LEAP-SRED database). Our estimates from the decomposition exercise imply that increasing Chinese import competition explains less than 2 per cent of the total increase in the TFP level in manufacturing for this period.

39 For the within-effect, we use the coefficient reported in column 1 in Table 3. If we use the size-specific coefficients reported in column 2, the within effect becomes positive (a positive contribution to the overall TFP change) but the absolute per cent level is nearly zero, increasing the total impact by about 6 percentage points. Hence, one may conclude that the within effect is either negative but relatively small or zero.

40 Or -6.82 per cent instead of -5.90 per cent (or -1.36 per cent per year instead of -1.18 per cent per year) based on the CPA data.

small firms which tend to be less productive in the initial period.

Conclusion

Utilizing as a natural experiment the rapid increase Chinese import share in the total domestic absorption in Canadian manufacturing, we find that rising Chinese import competition led to declines in R&D expenditure and TFP within firms. Especially, the declines in R&D and TFP were pronounced in smaller, less profitable, and less productive firms. The negative effect of China on R&D at the aggregate level is somewhat limited as the most-affected firms accounted for a small share of the total R&D expenditure in Canadian manufacturing. Rising import competition reallocated employment towards more productive firms and drove less productive firms out of the domestic market, more than offsetting the negative within-effects on TFP at the aggregate level.

References

Acemoglu, Daron (2008) "Equilibrium Bias of Technology," *Econometrica*, Vol. 75, No. 5, pp. 1371-1409.

Acemoglu, Daron, David H. Autor, David Dorn, Gordon H. Hanson and Brendan Price (2016) "Import Competition and the Great US Employment Sag of the 2000s," *Journal of Labor Economics*, Vol. 34, No. S1, Part 2, pp. S141-S198.

Aghion, Philippe, Nicholas Bloom, Richard Blundell, Rachel Griffith and Peter Howitt (2005) "Competition and Innovation: An Inverted U Relationship," *Quarterly Journal of Economics*, Vol. 120, No. 2, pp. 701-728.

Autor, David H., David Dorn and Gordon H. Hanson (2013) "The China Syndrome: Local Labor Market Effects of Import Competition in the United States," *American Economic Review*, Vol. 103, No. 6, pp. 2121-2168.

Autor, David, David Dorn, Gordon Hansen, Gary Pisano and Pian Shu (2017) "Foreign Competition and Domestic Innovation: Evidence from U.S. Patents," Mimeo, December.

Baily, Martin, Charles Hulten and David Campbell (1992) "Productivity Dynamics in Manufacturing Firms," *Brookings Papers on Economic Activity: Microeconomics*, Vol. 4, pp. 187-267.

Baldwin, John R., Afshan Dar-Brodeur and Beiling Yan (2016) "Innovation and Export-market Participation in Canadian Manufacturing," Statistics Canada, Analytical Studies Branch Research Paper Series, No. 386, 11F0019M.

Bartel, Ann, Casey Ichinowski and Kathryn Shaw (2007) "How Does Information Technology Really Affect Productivity? Plant-level Comparisons of Product Innovation, Process Improvement and Worker Skills," *Quarterly Journal of Economics*, Vol. 122, No. 4, pp. 1721-1758.

Bernard, Andrew, Bradford Jensen and Peter Schott (2006) "Survival of the Best Fit: Exposure to Low-wage Countries and the (uneven) Growth of US Manufacturing Establishments," *Journal of International Economics*, Vol. 68, No. 1, pp. 219-237.

Bloom, Nicholas, Mirko Draca and John Van Reenen (2016) "Trade Induced Technical Change? The Impact of Chinese Imports on Innovation, IT and Productivity," *Review of Economic Studies*, Vol. 83, pp. 87-117.

Bloom, Nicholas, Paul Romer, Stephen Terry and John Van Reenen (2015) "A Trapped Factor Model of Innovation", LSE/Stanford mimeo.

Bloom, Nicholas, Mark Schankerman, and John Van Reenen (2013) "Identifying Technology Spillovers and Product Market Rivalry," *Econometrica*, Vol. 81, No. 4, pp. 1347–1393.

Blundell, Richard and Stephen Bond (1998) "Initial Conditions and Moment Restrictions in Dynamic Panel Data Models," *Journal of Econometrics*, Vol. 87, No. 1, pp. 115–143.

Bugamelli, Matteo, Fabiano Schivardi and Roberto Zizza (2008) "The Euro and Firm Restructuring," NBER Working Papers, No. 14454.

Burstein, Ariel and Jonathan Vogel (2017) "International Trade, Technology, and the Skill Premium," *Journal of Political Economy*, Vol. 125, No. 5, pp. 1356-1412.

Brandt, L., J. Van Biesebroeck, L. Wang and Y. Zhang (2012) "WTO Accession and Performance of Chinese Manufacturing Firms," Centre for Economic Policy Research.

Card, David (2001) "Immigrant Inflows, Native Outflows, and the Local Labor Market Impacts of Higher Immigration," *Journal of Labor Economics*, Vol. 19, No. 1, pp. 22-64.

Dasgupta, Partha and Joseph Stiglitz (1980) "Industrial Structure and the Nature of Innovative Activity," *Economic Journal*, Vol. 90, No. 358, pp. 266-293.

Foster, Lucia, John Haltiwanger and C. J. Krizan (2000) "Aggregate Productivity Growth: Lessons from Microeconomic Evidence," New Developments in Productivity Analysis, NBER, Chicago Press.

Freeman, Richard and Morris Kleiner (2005) "The Last American Shoe Manufacturers," *Industrial Relations*, Vol. 44, pp. 307-342.

Gong, Kaiji and Rui Xu (2017) "Does Import Competition Induce R&D Reallocation? Evidecne from the U.S.," IMP Working Paper, WP/17/253.

Hall, Bronwyn H. (1992) "Investment and Research and Development at the Firm Level: Does the Source of Financing Matter?," NBER Working Paper No. 4096.

Keung Lorenz, Nicholas Li and Mu-Jeung Yang (2016) "The Impact of Emerging Market Competition on Innovation and Business Strategy," NBER Working Paper, No. 22840.

Kim, Myeongwan (2018a) "Rising Import Competition in Canada and its Employment Effect by Skill Group: Evidence from the 'China shock'," CSLS Research Report 2018-02, August. http://www.csls.ca/reports/csls2018-02.pdf.

Kim, Myeongwan (2018b) "Rising Import Competition in Canada and its Employment Effect by Gender: Evidence from the 'China shock'," CSLS Research Report 2018-03, August. http://www.csls.ca/reports/csls2018-03.pdf.

Kim, Myeongwan (2019) "Does Import Competition Reduce Domestic Innovation? Evidence from the 'China Shock' and Firm-Level Data on Canadian Manufacturing," CSLS Research Report 2019-03, August, http://www.csls.ca/reports/csls2019-03.pdf.

Kim, Myeongwan and John Lester (2019) "R&D spillovers in Canadian Industry: Evidence from a New Micro Data," CSLS research report 2019-02, August, http://www.csls.ca/reports/csls2019-02.pdf.

Krugman, Paul (1980) "Scale Economies, Product Differentiation, and the Pattern of Trade," *American Economic Review*, Vol. 70, No. 5, pp. 950–959.

Melitz, Marc J. (2003) "The Impact of Trade on Intra-industry Reallocations and Aggregate Industry Productivity," *Econometrica*, 71, 6,pp. 1695–1725.

Murray, Alexander (2017) "The Effect of Import Competition on Employment in Canada: Evidence from the 'China Shock'," CSLS Research Report 2017-03, July. http://www.csls.ca/reports/csls2017-03.pdf.

Pierce, Justin R. and Peter K. Schott (2012) "A Concordance between Ten-Digit U.S. Harmonized System Codes and SIC/NAICS Product Classes and Industries," *Journal of Economic and Social Measurement*, Vol. 37, No. 1-2, pp. 61-96.

Schmidt, Klaus (1997) "Managerial Incentives and Product Market Competition," *Review of Economic Studies*, Vol. 64, No. 2, pp. 191–213.

Shu Pian and Claudia Steinwender (2018) "The Impact of Trade Liberalization on Firm Productivity and Innovation," NBER Working Paper, No. 24715.

Appendix

Table A1: Summary Statistics, R&D Sample, by Initial Employment Size, Manufacturing, 2000-2012

Employment	R&D	Initial expenditure	Initial Profitability	ΔIP Productivity	ΔIPE	Δ ln(TFP)	ΔProfitability	
Total								
Mean	85	430	-0.009	-0.051	0.049	0.077	0.073	-4.957
Std. Dev.	494	6,606	x	0.685	0.102	0.143	0.788	x
Small								
Mean	24	129	-0.016	-0.068	0.050	0.080	0.057	-5.225
Std. Dev.	32	474	x	0.675	0.099	0.141	0.772	x
Medium								
Mean	182	600	0.035	0.004	0.045	0.065	0.136	-3.520
Std. Dev.	134	2,025	x	0.693	0.109	0.140	0.805	x
Large								
Mean	1,694	9,668	0.055	0.252	0.030	0.042	0.257	-2.440
Std. Dev.	2,543	39,500	x	0.844	0.160	0.204	1.070	x

Note: The number of observations is 116,683 (small: 100,894; medium-sized: 12,740; large: 3,049). Δ denotes a 5-year difference. All the initial values are the values observed in the initial year of a given sub-period. Employment is measured as the average labour unit. We define the three size groups based on the average labour unit (ALU) observed in the initial period (*e.g.*, ALU in 2000 for the 2000-2005 sub-period): small ($ALU < 100$); medium ($100 \leq ALU < 500$); and large ($500 \leq$). R&D expenditure is in thousand 2007 constant CAD. Productivity is measured as log of deviation from the industry average. Profitability is defined as net income or loss before tax divided by sales. x indicates that the statistics is suppressed due to confidentiality requirements.

Table A2: Summary Statistics, TFP Sample, by Initial Employment Size, Manufacturing, 2000-2012

	Employment	Initial Profitability	Initial Productivity	ΔIP	ΔIPE	Δ ln(TFP)	ΔProfitability
Total							
Mean	41	0.048	-0.010	0.051	0.073	0.057	-0.695
Std. Dev.	291	x	0.519	0.093	0.133	0.506	x
Small							
Mean	16	0.048	-0.067	0.051	0.074	0.052	-0.742
Std. Dev.	23	x	0.509	0.091	0.132	0.499	x
Medium							
Mean	183	0.050	0.003	0.045	0.062	0.116	-0.017
Std. Dev.	127	x	0.598	0.102	0.130	0.576	x
Large							
Mean	1,578	0.074	0.249	0.029	0.041	0.155	0.013
Std. Dev.	2,366	x	0.765	0.169	0.207	0.672	x

Note: The number of observations is 241,054 (small: 225,697; medium-sized: 12,886; large: 2,471). Δ denotes a 5-year difference. All the initial value is the value observed in the initial year of a given sub-period. Employment is measured as the average labour unit. We define the three size groups based on the average labour unit (ALU) observed in the initial period (*e.g.* ALU in 2000 for the 2000-2005 sub-period): small ($ALU < 100$); medium ($100 \leq ALU < 500$); and large ($500 \leq$). Initial productivity is measured as log of deviation from the industry average. Profitability is defined as net income or loss before tax divided by sales. x indicates that the statistics is suppressed due to confidentiality requirements.