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Working Paper

Origin Matters: The Differential Impact of Import Competition on Innovation?

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Ross School of Business Working Paper
Working Paper No. 1299
December 2015

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Abstract

We examine the impact of import competition on firms' innovation input and output. We conjecture that U.S. firms view import competition from high-wage countries (HWCs) as "neck-and-neck" competition and will respond by intensifying innovation. In contrast, U.S. firms will reduce innovation in response to import competition from low-wage countries (LWCs), because such competition does not always increase the potential benefits from innovation. Our empirical results are supportive. We find that, when confronting HWC import competition, U.S. firms increase R&D spending while intensifying and improving innovation output (file more patents, receive more citations to their patents, and produce more breakthrough patents). Moreover, U.S. firms closest to the technological frontier—largest firms, firms with the largest stocks of knowledge, and most profitable firms—increase and improve their innovation the most in response to HWC competition. These results shed light on the relationship between product market competition and innovation, and point to the origin of import competition as a determent of innovation decisions made by U.S. companies.

Key words: imports, competition, R&D, Innovation, Patent

JEL classification codes: F61 O31 O32

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We thank Seth Carnahan, Michael Jensen, Amy Nguyen-Chyung, Jim Ostler, and seminar participants at the Ross School of Business for their helpful comments. All errors are our own.

1. Introduction

A large body of literature since at least Schumpeter (1942) has explored the relationship between product market competition and innovation. However, neither theoretical predictions nor empirical evidence have been conclusive.[1] Firms with market power are in a better position to innovate because they possess more resources to invest in innovation and can amortize innovation investments over a larger scale; meanwhile, they may have less incentive to innovate because they fear innovation can rapidly replace their monopolistic rents. Recent efforts have found the competition-innovation relation to be non-monotonic. The relation depends on, among other things, the nature of the industry rivalry (Aghion *et al.*, 2005; Lee, 2005), firm innovation strategy (Artés, 2009; Boone, 2000), and incumbent technological capabilities (Lee, 2009; Tang, 2006).

In this study, we revisit this long-debated relationship between market competition and firm innovation. We extend these lines of inquiry by distinguishing between two types of market competition—that from technologically advanced entrants versus laggard entrants—and between two types of incumbent firms—those close to, versus those far away from, the technology frontier. In particular, we focus on industry-level import competition from advanced or high-wage countries (HWCs) and import competition from low-wage countries (LWCs). Import competition from LWCs represents competition in a different spectrum than import competition from HWCs. For instance, Amiti and Khandelwal (2012) document significant quality differences among products imported by the U.S. from countries of various income levels. Schott (2008) shows that quality difference of imported products measured by unit value, a wedge he calls the "OECD premium," widened, rather than shrank, over time.

Using industry-level import competition to measure market structure offers several benefits. First, it is less endogenous to firm decision than domestic market structure that has been examined in most prior research, and may help us better identify the impact of changes in market competition.[2] Second, the landscape of U.S. imports has undergone substantial changes over the past several decades. Figure 1 shows that U.S. imports from HWCs experienced steady increases over the entire sample period; meanwhile, imports from LWCs remained very small through the 1970s and 80s, but began to surge in the 90s, mainly driven by imports from China. Furthermore, different industries have been exposed to different import competition pressure over the years, which provide cross-sectional variation.

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[1] For recent excellent reviews of this literature, see Ahuja, Lampert, and Tandon (2008), Cohen (2010), and Gilbert (2006).

[2] Market structure has been measured by price-cost margins (Aghion *et al.*, 2005; Nickell, 1996), Herfindahl index (Tingvall & Poldahl, 2006), concentration ratio (Levin, Cohen, & Mowery, 1985; Scherer, 1967), number of competitors (e.g., Kraft, 1989), number of new companies, market shares or market growth (Geroski, 1990).

Insert Figure 1 about here

We conjecture that firms in the U.S. and HWCs are similar in technological capabilities. U.S. firms will view import competition from HWCs more likely to be "neck-and-neck" competition and intensify innovation to stay ahead. In contrast, firms in LWCs lag U.S. firms in technological capabilities, but abundant labor supply and aggressive trade policies of their home countries enable them to export products that offer a relatively cheaper option in the importing countries. Therefore, U.S. firms will expect import competition from LWCs to significantly lower their profit margins, and lower their potential benefits from innovation. In response, they will focus on short-term actions and tend to reduce innovation.

We test these conjectures using a sample of 4,959 U.S. public-listed manufacturing firms between 1976 and 2005. We measure import competition using U.S. imports of the products in a firm's primary industry divided by total U.S. domestic expenditure on these products, but distinguish between import competition from HWCs and LWCs. We measure a firm's innovation input by its R&D expenditures, and a firm's innovation output by its patents filed with the U.S. Patents and Trademarks Office (USPTO). We study several features of these patents, including (1) quantity, measured as the number of patents (Griliches, 1990); (2) quality, measured as the total number of citations received by these patents (Trajtenberg, 1990); and (3) novelty, measured as the number of breakthrough patents (Ahuja & Lampert, 2001). Figure 2 provides industry-level evidence of the relationships between changes in patents and changes in import competition from HWCs and LWCs, respectively. The positive-sloped fitted line between the number of patents and import competition from HWCs (left panel) stands in contrast to the level-sloped relationship between changes in number of patents and import competition from LWCs (right panel).

Insert Figure 2 about here

Our firm-level regression results support the industry-level patterns presented in Figure 2. In particular, firms exposed to greater import competition from HWCs subsequently invest more heavily in R&D and achieve a greater innovation output. The economic significance of the estimates is substantial. They imply that, holding everything else constant, a 10-percentage-point increase in import competition from HWCs would increase a firm's

R&D expenditures by about 7% and number of patents by over 5%. In addition, firms facing HWC import competition receive more citations to their patents and have more breakthrough patents. In contrast, firms facing greater import competition from LWCs reduce their R&D expenditures and file fewer patents. These results confirm that different types of competition elicit different responses in firms' R&D strategy.

Next, we explore the heterogeneous impact of import competition on innovation in the cross-section. Among U.S. firms, we expect the industry leaders to intensify innovation the most in response to import competition from HWCs. We use three measures to approximate firms' position within an industry: (1) size, (2) knowledge (patent) stock, and (3) profitability. Consistent with our conjectures, we find that when facing import competition from HWCs, industry leaders intensify innovation (and improve their innovation output) the most. Meanwhile, industry laggards are only responsive to import competition from LWCs.

Our paper contributes, first, to the literature on the relationships between product competition and innovation. To the best of our knowledge, our paper is the first to decompose market competition into different spectrums and finds that firms, depending on their industry positions, responds to different competition differently. It complements recent efforts to examine heterogeneity in technological levels among incumbent firms (Lee, 2009; Tang, 2006). Recent papers find that European firms facing import competition from China normally increase innovation (Bloom, Draca, & Van Reenen, 2016), but European firms lagging far behind U.S. firms in terms of technology capabilities reduce innovation when faced with import competition (Aghion *et al.*, 2009). Such results will be difficult to reconcile without differentiating between the technological capabilities of firms in the importing countries and their competitors in the exporting countries. Imports from HWCs may represent more comparative technological advantage to U.S. firms than imports from LWCs. Hence, U.S. firms face more technological competition when import competition from HWCs (rather than LWCs) increases. As a result, the impact of HWC and LWC imports on innovation will be different.

In addition, this paper studies not only innovation input (R&D) and output (patents) in terms of quantity, but also the quality and novelty of patents, thereby connecting the competition–innovation literature with the emerging literature on radical inventions and highlighting one circumstance under which existing firms become a source of radical inventions (Ahuja & Lampert, 2001; Eggers & Kaul, 2014). Finally, although it has been widely documented that patents tend to be concentrated in large firms (e.g., Nanda, Younge, & Fleming, 2013), our study highlights one of the circumstances in which large firms enhance competitive advantage against small firms.

Our paper also contributes to an emerging literature on import competition from LWCs and firm performance. While much has been found about how trade with LWCs has depressed wages and employment in the U.S. (Autor, Dorn, & Hanson, 2013; Bernard, Jensen, & Schott, 2006; Ebenstein *et al.*, 2014), little attention has been paid to the impact of import competition from LWCs on firms' innovation. This paper illuminates how innovation by domestic firms varies in response to trade with different countries.

The rest of the paper is organized as follows. In Section 2, we discuss the relevant literature. Section 3 describes our data, sample, and variables, and presents summary statistics. Section 4 presents the empirical specifications. Section 5 analyzes the effects of import competition on firm innovation. Section 6 explores the mechanisms. Section 7 concludes.

2. Related Literature and Theoretical Motivation

As reviewed by Ahuja *et al.* (2008), Cohen (2010), and Gilbert (2006), theoretical models about the relationship between competition and innovation have yet to generate conclusive predictions.[3] Schumpeter (1942) posits that firms with market power have stronger incentive to invest. This is because these firms are more likely to accumulate the resources necessary to invest in innovative activity. In addition, they are able to amortize their innovation investments over a large scale and hence benefit from a lower unit cost of innovation.

While theorists agree with Schumpeter's fundamental argument, they do not necessarily agree on how such market power would arise. On the one hand, Schumpeter believes that pre-innovation market power confers post-innovation market power. Consistent with such belief, Gilbert and David (1982) argue that an incumbent monopolist will invest more in R&D to ward off a potential entrant, and Dasgupta and Stiglitz (1980) show that firms' R&D intensities decline as an industry becomes more competitive. On the other hand, some scholars have argued that a more competitive market, rather than a more concentrated one, will encourage innovative activities. This is because firms in more competitive markets will gain more from innovation on the margin, whereas firms innovating in more concentrated markets may suffer a "replacement effect": the possibility that their innovation will partially displace oligopolistic rents captured before the innovation (Arrow, 1962). Firms insulated from competition may also become more bureaucratic and therefore less innovative over time (Scherer, 1980).

Recent models highlight incumbent firms' incentive to innovate as driven by the *difference* between their post-innovation and pre-innovation rents. Aghion et al. (2005, 2009) argue that in sectors where firms operate at similar technological levels, competition reduces firms' pre-innovation rents by more than it reduces their post innovation rents, hence firms

[3] The empirical evidence has been mixed. Some papers find a positive relation between monopoly power and R&D (see, e.g., Blundell, Griffith, & van Reenen, 1999; Kraft, 1989), others find a negative relation (Geroski, 1990), Nickel 1996), or nil effect (Levin *et al.*, 1985).

will intensify their innovation effort to escape "neck-and-neck" competition. On the other hand, in sectors where firms lag in technology capabilities and operate with a thin margin, competition will mainly affect post-innovation rents, and firms will therefore reduce innovation. Similar arguments have also been made in the patent-race literature: that firms with similar knowledge stocks will compete aggressively to gain success, while lagging firms will drop out (Fudenberg *et al.*, 1983; Harris & Vickers, 1985).

A related literature studies the relationship between firm characteristics and innovation. One of the most studied firm characteristics is firm size. While Schumpeter argues in his earlier work that entrepreneurs outside large firms are the major source of innovation (Schumpeter, 1934), his later work argues that larger firms are expected to enjoy more market power, can amortize their innovation investments over a larger scale, and hence have greater incentive to invest in innovation (Schumpeter, 1942). Empirical evidence largely indicates that firm size is positively related to both innovation input (R&D expenditure) and output (patents). Other firm characteristics studied in the literature include cash flow and firm scope, both of which are found to be positively correlated with innovation (Ahuja, Lampert, & Tandon, 2014; Nelson, 1959; Rosen, 1991).

In sum, the existing literature on competition and innovation appears to have three gaps. First, although recent models have taken into account the heterogeneity in firms' technological capabilities, this heterogeneity has been studied at the sector level. However, firms within the same sector differ in their technological capabilities. Facing strong entry threat within a sector, incumbent firms closer to the technology frontier will expect to survive entry threat, and will intensify innovation to escape competition, whereas incumbent firms far away from the technology frontier will expect to have a lower chance of survival or profit margin after entry and therefore will be discouraged from innovating. Second, the existing literature implicitly assumes that entrants are at least as strong as incumbent firms in their technological capabilities, if not stronger. This is inconsistent with the reality of global competition. While imports from HWCs may represent comparative technological advantage with respect to U.S. firms, imports from LWCs may be a result of cheap labor without innovative components. Hence U.S. firms face more technological competition when import competition from HWCs increases, but more endowment cost competition when import competition from LWCs increases. As a result, the response in innovative activities will depend in part on the origin of that competition.

Finally, the existing literature is predominantly focused on the size of R&D expenditure; the quantity and quality of innovation output are less emphasized. Radical or "breakthrough" inventions lie at the core of entrepreneurial activity and wealth creation (Schumpeter, 1942). They serve as the basis of new technological trajectories and paradigms and are an important source of creative destruction. To the extent that firms may change not only their inputs to innovation, but also the direction of their innovative activities, it is important to examine these aspects of innovation in response to competition.

To fill these gaps, we distinguish between different types of entry competition—technologically advanced entrants versus laggard entrants—and between different types of incumbent firms—those industry leaders and those laggards. To provide a full picture of how firms innovate, we study the impact of import competition not only on innovation input (R&D expenditures), but also on the quantity, quality, and direction of innovation output.

3. Data and Variables

3.1. Data and Sample

We build our sample by combining (1) firm-level accounting data from COMPUSTAT, (2) industry-level (4-digit 1987 SIC) import and shipment data from the National Bureau of Economic Research (NBER) and the U.S. Census Bureau (Becker, Gray, & Marvakov, 2013; Schott, 2008), and (3) patent data from the 2006 edition of the NBER patent database (Hall, Jaffe, & Trajtenberg, 2001).[4]

3.2. Innovation Input and Innovation Output

We measure a firm's innovation input using its annual R&D expenditures and a firm's innovation output using the number of patents it filed in a given year. To account for the time lag and for the long-term nature of the innovation process, our empirical tests relate firm characteristics and import competition in the current year to the number of patent applications (that are eventually granted) three years later.

In addition to simple patent counts, we also study quality and novelty of a firm's patents. We measure the technological and economic importance of a firm's patents using the patents' citation counts (Trajtenberg, 1990). We measure the novelty of a firm's patents by counting the number of breakthrough patents (Ahuja & Lampert, 2001). Following previous studies, we set patent and citation counts to zero for sample firms without available patent or citation information. We also set R&D to zero for firms with missing values of R&D expenditures in COMPUSTAT.

Our final sample contains an unbalanced panel of about 5,000 publicly-listed firms for the years 1976–2005, for a total of about 50,000 firm–year observations.

3.3. Import Competition

[4] Patents are included in the database only if they are eventually granted before 2006, when the latest version of the patent database is available.

We calculate an industry's exposure to import competition from HWCs (LWCs) as the ratio of U.S. imports of products in the firm's primary industry from HWCs (LWCs) to total U.S. consumption of products in this industry (domestic shipments plus total imports minus total exports). The formula is listed below.

$$\text{Import penetration from HWCs} = \frac{\text{U.S. imports from HWCs}}{\text{U.S.outputs+U.S.imports-U.S.exports}};$$

$$\text{Import penetration from LWCs} = \frac{\text{U.S. imports from LWCs}}{\text{U.S.outputs+U.S.imports-U.S.exports}}.$$

The list of LWCs, as shown in the Appendix, is obtained directly from Bernard, Jensen, and Schott (2006). They classify a country as an LWC if its annual per capita GDP is less than 5% of the U.S. annual per capita GDP, from 1972 to 1992. China, India, and most African countries are on the list. Countries not on the list are categorized as HWCs.

Figure 1 shows that import competition from HWCs rose steadily over the entire sample period, along with imports from OECD countries. Import competition from LWCs was very low in the 1970s and 80s but started to rise in the early 1990s, driven mostly by imports from China.[5] A closer look at the trade data reveals that industries vary significantly in their exposure to import competition over time. In 1980, the top three industries facing the most import competition from HWCs were 3339 (Primary Smelting and Refining of Nonferrous Metals, Except Copper and Aluminum), 2611 (Pulp Mills), and 3751 (Motorcycles, Bicycles, and Parts); by 2000, only 3339 remained among the top three, and the two other industries most exposed to import competition from HWCs had changed to 3569 (General Industrial Machinery and Equipment), and 3493 (Steel Springs). In 1980, the three industries facing the most import competition from LWCs were 2299 (Textile other), 3915 (Jewelers' Findings and Materials, and Lapidary Work), and 2381 (Dress and Work Gloves, Except Knit and All-Leather); by 2000, they had changed to 3942 (Dolls and Stuffed Toys), 2386 (Leather and Sheep-Lined Clothing), and 3149 (Footwear, Except Rubber). Interestingly, the footwear industry (3149) ranked the 5th highest industry subject to import competition from HWCs in 1980 but ranked the 3rd highest industry subject to import competition from LWCs in 2000. In sum, industries have varied over time in their exposure to import competition from HWCs and LWCs, respectively.

[5] To check the robustness of our results, we also used imports from OECD countries and China to proxy for imports from HWCs and LWCs, respectively. Our main results remained qualitatively unchanged.

3.4. Summary Statistics

Summary statistics for the key variables are presented in Table 1. On average, a firm spends a little over eight percent of its asset value on R&D, files 13 patents, and receives 105 citations to its patents every year. These variables are right-skewed, as evidenced by the relatively big standard deviations.

Our matched firms are large firms with an average of $1.5 billion in sales or assets. The average value of import competition is about 20%. Although the average import competition is mostly from HWCs in our thirty-year sample period, import competition from LWCs has grown steadily over these years.

Insert Table 1 about here

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4. Empirical Results

4.1. Specification

Our main empirical specification is the following:

$$\text{Innovation}_{\text{ij,t+}\tau} = \alpha + \beta_1 \text{HWC Import Competition}_{j,t} + \beta_2 \text{LWC Import Competition}_{j,t} + X\gamma + \varepsilon, (1)$$

In the above equation, $\text{Innovation}_{ij,t+\tau}$ represents the innovation characteristics of firm *i* in industry *j* and year *t+τ*. Innovation characteristics include R&D expenditures, patent and citation counts, and patent novelty. X is a vector of control variables such as firm size, age, cash, scope (number of business segments), and an industry-level measure of domestic product market competition: the Herfindahl Index (HHI). The coefficients of interest are β_1 and β_2. We also perform a t-test of the differences between β_1 and β_2. This specification allows us to analyze how ex-ante import competition affects innovation *τ* years later. We opt to use a three-year lag for patent regressions, but our results are qualitatively unchanged if we use two-year or even one-year lags. All the regressions include year and industry fixed effects, where an industry is defined at the 3-digit-SIC level. We cluster the standard errors at the firm level. We choose to include industry fixed effects rather than firm fixed effects because our key variables of interest are at the industry level. Import penetration only changes slowly and gradually during a long period of time. In Compustat, each firm is associated with a fixed industry classification, so adding firm fixed effects might absorb much of variation in industry import penetration and makes it difficult to estimate the variable of interest. Moreover, many prominent papers exploring the determinants of patent outcomes adopt industry fixed effects rather than firm fixed effects (Ahuja & Lampert, 2001; Hirshleifer, Low, & Teoh, 2012).

4.2. Import Competition and Innovation Input

We first estimate how import competition affects firms' R&D expenditures in Table 2. Across all columns, coefficients for the control variables are consistent with other studies on corporate R&D: Larger firms, firms with more cash holding tend to invest more in R&D, whereas older firms spend less. In addition, firms spend less in R&D as the HHI measure of domestic market concentration increases. Firm scope, as measured by the logarithm of the number of segments, does not seem to significantly impact R&D.

Insert Table 2 about here

Column (1) shows that greater import competition is associated with greater R&D expenditures. However, columns (2) to (4) show that aggregating import competition across those from HWCs and LWCs masks important differences in their impacts on firms' R&D expenditures. The economic significance of the point estimate is substantial. Coefficients in Column (4) imply that a ten-percentage-point increase in HWC import competition would prompt firms to increase R&D expenditures by a little over 7%, while a ten-percentage-point increase in LWC import competition would trigger a reduction in R&D expenditures of about 13%. The difference between coefficient estimate on HWC and LWC is statistically significant. We then move from innovation inputs and innovation outcomes.

4.3. Import Competition and Innovation Output

4.3.1. Patent counts

Table 3 estimates firms' patent counts against our import competition measures. Across all columns, coefficients for the control variables are generally consistent with those in Table 2: Larger firms and firms with more cash tend to generate more patents, though firm age and scope do not matter for patents in a significant fashion. Notably, industry HHI does not seem to significantly impact patent counts, after our import competition variables are controlled for.

Insert Table 3 about here

Column (1) shows that greater import competition spurs more patent filings in general. However, columns (2) and (3) show that this effect is almost entirely driven by import competition from HWCs. Import competition from LWCs is negatively associated with patent counts, although this effect is statistically insignificant. The economic impact of HWC imports on patent counts is considerable. Coefficients in Column (4) show that, on average, a ten-percentage-point increase in import competition from HWCs is associated with a 5.3% increase of a firm's patent filings. The difference between HWC and LWC coefficient estimate is significant at 5% level.

4.3.2. Patent citations

Table 4 estimates the quality of a firm's innovations against import competition. We measure innovation quality using the total number of citations a firm gets before 2006 to all of its patents filed in a given year. Results are very similar to those in Table 3. Firms facing import competition from HWCs receive more citations to their patents. According to the coefficients, on average, a 10-percentage-point increase in import competition from HWCs is associated with additional 5.7% citations. In contrast, import competition from LWCs does not have a significant impact on patent citation; the differences in patent citations in response to HWC vs. LWC import competition are statistically significant at the 1% level. Recall that results in Table 3 shows that firms file 5.3% more patents. We can see that the increased citations arise not only from increased number of patents, but also from the increased citations per patent.

Insert Table 4 about here

A main drawback of measuring innovation quality using citation is that citations are received for many years after a patent is created. Patents created near the ending year of a sample period have less time to accumulate citations, therefore patent citations used in most empirical studies suffer from a time truncation bias. For instance, it is not obvious whether a 1990 patent that received 5 citations by 1999 should be thought of as more or less highly cited than a 1985 patent that received 10 citations by 1999.

To address this issue, we follow the recommendations of Hall, Jaffe, and Trajtenberg (2005; 2001) and adjust the patent citation counts. The way of adjusting is to multiply each patent's citation count with a weighting index from Hall *et al.* (2001) that involves scaling citation counts by dividing them by the average citation count for a group of patents to which the patent of interest belongs. This approach treats a patent that received say 11 citations and belongs to a group in which the average patent received 10 citations, as equivalent to a patent that received 22 citations, but happens to belong to a group in which the average was 20. As a robustness test, we also use an alternative measure, *Weighted citation*, which is the sum of the adjusted patent citations across all patents applied during each year; results are almost the same with this alternative measure.

4.3.3. Patent novelty

We proceed to explore the novelty of the patents in the technological field. Following Ahuja and Lampert (2001), we count the number of a firm's patents that belong to the top 1% most cited patents ("breakthrough patents") among all patents filed in a given year. Results in Table 5 show that firms generate more breakthrough patents when faced with import competition from HWCs, and firms generate fewer breakthrough patents when faced with import competition from LWCs.

Insert Table 5 about here

4.4. Firms' Responses: Leaders versus Laggards.

In this subsection we explore the heterogeneous impact of import competition on innovation among U.S. firms. Van Dijk *et al.* (1997) raise the question of differential effects of market structure on small versus large firms' innovative activity. Boone (2000) predicts that the effect of market competition on a firm's incentive to innovate depends on its level of cost efficiency relative to the efficiency levels of its rivals. Lee (2009) finds that firm's R&D response to competitive market pressure depends primarily on its level of technological competence. In a similar vein, we examine how firms respond to import competition depending on a firm's relative capability in an industry measured in terms of: (1) size, (2) patent stock, and (3) profit margin. We measure firm size based on annual sales. We measure knowledge stock using total number of patents. We measure profitability using gross profits divided by annual sales. We sort firms based on size, knowledge stock, and profitability in each 2-digit SIC industry every year. The dummy variable, Leader (Laggard), refers to firms in the top (bottom) tercile among their industry peers in terms of the above three characteristics each year.[6]

[6] We do not have a strong theoretical justification for our definition of leaders/laggards except for the comparison convenience. We refer to firms in the top tercile as leaders, and firms in the bottom as laggards; the middle tercile serves as the outside/benchmark group in regressions with both leader and laggard dummies. We experiment with other cutoffs to check the robustness of our results. For example,

To explore firm heterogeneity, we augment the Equation (1) with additional interaction terms in Equation (2)

$$\begin{aligned}\text{Innovation}_{ij,t+\tau} = {} & \alpha + \beta_1 \text{HWCImportCompetition}_{j,t} + \beta_2 \text{LWCImportCompetition}_{j,t} + \\ & \beta_3 H\text{WCImportCompetition}_{j,t} * \text{Leader}_{i,t} + \beta_4 \text{LWCImportCompetition}_{j,t} * \text{Leader}_{i,t} + \\ & \beta_5 H\text{WCImportCompetition}_{j,t} * \text{Laggard}_{i,t} + \beta_6 \text{LWCImportCompetition}_{j,t} * \text{Laggard}_{i,t} \\ & + \beta_7 \text{Leader}_{i,t} + \beta_8 \text{Laggard}_{i,t} + X\gamma + \varepsilon, (2)\end{aligned}$$

Results in Table 6 show that the main effect of import competition from HWCs and LWCs observed in Table 2 through Table 5 continue to hold. It is reassuring to observe that leaders, measured in the above three ways, are associated with significantly better innovation outcomes. In addition, columns (1) and (2) show that, the largest firms invest more in R&D and generate more patents than smaller firms. In addition, they respond the most positively to import competition from HWCs, but rather passively to import competition from LWCs. On the contrary, the smaller firms invest less and file fewer patents when facing HWC import competition but they tend to respond positively to LWC importation competition. Columns (3) and (4) show that firms with the largest knowledge stocks invest more in R&D and generate more patents than firms with smaller knowledge stocks. In addition, they respond the most positively to import competition from HWCs. Columns (5) and (6) show some weak evidence that the most profitable firms invest more in R&D and generate more patents than less profitable firms. In addition, they respond most positively to import competition from HWCs. In sum, we find that U.S. firms tend to respond to different spectrums of competition based on their relative industry positions.

Insert Table 6 about here

Overall, the results in Table 2 through Table 6 suggest that when facing competitive pressure from HWCs, U.S. firms, especially the industry leading firms, invest more in R&D and subsequently generate more patents, receive more citations to their patents, and generate more breakthrough patents. In contrast, when facing competitive pressure from LWCs, U.S. firms tend to lower R&D expenditures, and their innovation outputs drop accordingly. There are also significant differences in the innovation input and output of leader and laggard firms when facing import competition from LWCs.

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we use top/bottom quartiles to define leaders/laggards; results are qualitatively similar to using terciles.

5. Mechanisms and Further Analysis

In this section we explore a few mechanisms that may explain the competition–innovation relationship we have shown in Section 4. We explore the mechanism that supports our conjecture—that, to U.S. firms, import competitions from HWCs and LWCs represent different degrees of technological competition and therefore prompt different firm responses in terms of innovation. We also entertain alternative hypotheses that could generate similar relationship between import competition and firm innovation.

5.1. Industry Life Cycles

One prominent alternative explanation for our results is that the competition-innovation patterns are driven by industry life cycles. Competition from HWCs is stronger in industries early in their life cycle (where returns to innovation and patenting are higher); as some industries decline in the later stage of their cycle and offshore production to LWCs, they are not undertaking more innovation as the technologies are fading away. Unfortunately, industry fixed effects do not sufficiently account for factors that coevolve with industry life cycles.

To address this shortcoming, we include in Table 7 re-estimates of the key specifications in Table 3-5 with industry (2-digit SIC) * year fixed effects. In addition to industry-specific life cycle factors, this specification also accounts for other unobservable industry-specific time varying factors, such as technological advances and demand shocks. Table 7 shows that with industry-year fixed effects, the point estimates are comparable to prior results and our main conclusions continue to hold.

Insert Table 7 about here

5.2. Import Competition and Technological Competition

Our main argument is that import competitions from HWCs and LWCs represent different degrees of technological competition to U.S. firms. If this is indeed the case, we should expect the effects of import competition to weaken once we directly control for technological competition from HWCs and LWCs, respectively.

Data on technological competition from HWCs and LWCs are difficult to obtain. As an approximation, we count patents filed by inventors from different countries in the USPTO as proxies for technological competition from these countries. Based on the USPTO database, we calculated that patents filed by HWC inventors (individuals and firms) rose from 30% of all patents filed in 1976 to 46% of all patents in 2005. In contrast, patents filed by LWC inventors are limited and account for only 0.3% of all patents filed in 2005.

For each patent technology class we calculate the share of patents filed by inventors from HWCs and LWCs, respectively. We then aggregate the shares to SIC level based on an SIC-technology class concordance (Silverman, 1999). We use these SIC-level share values as proxies for technological competition from HWCs and LWCs, respectively.

Table 8 repeats the main regressions in Equation (1) but includes technological competition variables from HWCs and LWCs as additional controls. Results across the columns show that technological competition has a strong impact on innovation in the same direction as import competition from corresponding sources. In addition, after controlling for technological competition, the impact of import competition significantly is reduced both economically and statistically when compared with tables 2–5 (Column 4). This evidence suggests that import competition affects innovation partially through "imported" technological competition.

Insert Table 8 about here

5.3. Import Competition versus Learning Opportunities

Rather than being a competitive threat, import competition from HWCs (or LWCs for that matter) could also enable U.S. firms to observe frontier technologies from overseas and hence provide opportunities for them to learn and imitate such technologies. To distinguish the competition effect from learning, we employ an instrumental-variables strategy, using import competition faced by other developed countries. The underlying identifying assumption is that imports by other high-income countries[7] are driven by common industry import demand shocks and supply shocks such as productivity growth and trade barrier reduction in LWCs (Autor, Dorn, and Hanson 2013).

We use share of imports by eight non-U.S. OECD countries to instrument for U.S. firms' HWC and LWC import competition variables. To construct the instruments, we use UN's Comtrade database starting from 1992, which was the first year UN's Comtrade database reported detailed industry level trade information. The first stage regression results reveal a statistically significant association between industry-level import exposure by US and by these eight high-income countries.

[7] Following Autor *et al.* (2013), the eight other high-income countries are Germany, Japan, Australia, New Zealand, Denmark, Finland, Spain, and Switzerland. We refer readers to their paper for a detailed description of the instrumental variable strategy.

We report the 2SLS results in Table 9. The results in column (1) to (4) also indicate that the 2SLS results actually strengthen our prior findings that imports from HWCs boost while imports from LWCs lower US firms' R&D and innovation.

Insert Table 9 about here

Upon observing "imported" technological opportunities, firms can also increase their innovative effort through global collaboration in innovative projects. To entertain this alternative mechanism, we used the Securities Data Company's (SDC) global alliance database to identify international R&D alliances in which U.S. firms join force with foreign partners. Because the SDC alliance database starts in 1985, we were only able to extract alliance information for the sub-sample period of 1985–2005. We observe that during this period, U.S. public firms established 38,024 international alliances with at least one foreign partner. Of these international alliances, around 90% featured a partner from a HWC and only 10% featured a partner from a LWC. In addition, R&D alliances accounted for 14% of all alliances with HWC partners but only 0.8% of all alliances with LWC partners.

Table 10 repeats the main regressions in Equation (1), but includes the number of a firm's international R&D alliances in HWCs and LWCs as additional control variables. Results across the columns show that number of international R&D alliances is positively correlated with the firms' innovation in U.S. However, after controlling for international R&D alliances, the effects of import competition remain similar to those in tables 2–5 (Column 4).

In a separate analysis, we estimated the probability of a U.S. firm establishing an international R&D alliance in response to HWC or LWC import competition. The results show that U.S. firms are more likely to establish international R&D alliances (especially with HWC partners) when facing import competition from HWCs, but they are not more likely to establish international R&D alliances when facing import competition from LWCs.[8]

Insert Table 10 about here

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[8] We do not report these results due to space concerns, but they are available from the authors upon request.

5.4. Import Competition versus Export Orientation

One might argue that the relationship we observe between import competition and firm innovation arises from the globalization of product market in general. Instead of competition, imports may just reflect the fact that industries are becoming more globalized. Greater imports from HWCs often accompany greater exports to HWCs, i.e., greater market opportunity in HWCs, which leads to more R&D. In contrast, greater market opportunity in LWCs means that US firms can "recycle" their old products in a bigger market; they therefore will spend less on R&D. Indeed, empirical evidence suggests that industries that import a lot also export a lot (Bernard *et al.*, 2007).

We construct two new variables, export orientation to HWCs (LWCs), to measure an industry's export orientation from U.S. to HWCs (LWCs) as a percentage of its total domestic output (shipment). In our sample, the correlation between import competition from HWCs and export orientation to HWCs is about 0.50. The correlation between import competition from LWCs and export orientation to LWCs is only about 0.05.

Table 11 repeats the main regressions in Equation (1) but includes export orientation variables to HWCs and LWCs as additional controls. Results across the columns show that export orientation indeed has an effect on innovation that is similar to the effect from import competition. However, after controlling for export orientation, the import competition variables continue to have a meaningful impact on firms' innovation.

Insert Table 11 about here

5.5. Intrafirm Trade and Global Sourcing

According to Ruhl (2015), intra-firm trade represents on average over 40% of the cross border product flows in the US. Rising intra-firm trade can come from either cheaper cost inputs from lower cost countries or different knowledge bases through higher wage countries. Therefore, a caveat with our measures of import competition is that they include both US firms' intra-firm (global sourcing) imports and foreign firm exporting into the US. Intrafirm imports cannot be considered as proper measures for competition.

We take two steps to address the possibility of global sourcing embedded in our import competition measure. First, we use publically available (post-2002) Census data to distinguish non-related party trade and related party trade. The results, shown in the first four columns in Table 12, indicate that our conclusions remain unaffected when we exclude the part of related party trade due to global sourcing. We have also attempted to obtain pre-2002 Census data but were told that data for pre-2002 years has incomplete coverage for countries and industries, which is confirmed by Ruhl (2015).

Second, we apply the average portion of related party trade calculated based on post-2002 data to construct an estimated amount of related party imports for the pre-2002 years and repeat the estimates in the first four columns in Table 12. In doing this, we take assurance from the finding in Ruhl (2015) that the portion of overall related party imports remains relatively stable within the range of 44% to 48% from 1992 to 2010. The results, presented in the last four columns in Table 12, bear a close resemblance to the results in the first four columns.

Still, we acknowledge that the overall portion of related party imports may conceal great variation in related party transactions across countries, industries, and years. This is a shortcoming that we cannot address with current available data and is left for future study.

Insert Table 12 about here

5.6. From Innovation to Imports?

Several studies show that the larger, more innovative firms are the ones investing in foreign direct investment and benefiting from cost and knowledge arbitrage through global sourcing from those foreign operations (Alcácer & Chung, 2007; Chung & Alcácer, 2002). In our setting, the possibility that innovative firms are driving foreign direct investment and global sourcing can cause a reverse causality problem. Empirically, we employ three approaches to address such concerns.

First, we examine the cross-sectional heterogeneity based on industry R&D intensity. In particular, we distinguish "High-Tech" industries (those industries with median firm's R&D/asset greater than or equal to 5% and "Low-Tech" industries (those industries with median firm's R&D/Asset less than 5%) and analyze whether our results differ. We report the results in Table 13 and show that the pattern of results between high-tech industry and low-tech industries is quite similar. This evidence suggests that our results are not driven in particular by R&D intensive firms.

Second, to some extent, the firms which can exploit innovations in foreign countries and using parent firm knowledge in foreign subsidiaries to generate inputs and final goods for the US market are more likely to be multinationals (MNCs). We therefore test our hypotheses separately on the sample of MNCs and domestic firms. The results, shown in Table 14, suggest that our conclusions continue to hold in the subsample of domestic firms, although the economic effects are not as strong as those for MNCs.

Third, we conduct a Granger causality test. In particular, we regress the two import competition variables on lagged values of industry median firm's patent number (as a proxy for industry innovativeness) and lagged values of the dependent variables, where we set the period of lags to be 4. The results, shown in Table 15, indicate that past industry innovation success does not Granger cause our import competition measures.

Insert Table 13, 14 and 15 about here

5.7. Further Robustness Checks

We perform a few tests to check the robustness of our results. One might argue that a country's wage is correlated with other country-level characteristics that could explain our findings. For instance, we use the national Intellectual Property Rights (IPR) index in Park (2008). The IPR index is assessed once every five years and consists of five indicators: the degree of legal protection, the range of legal protection, membership of international patent organizations, compensation for infringement as well as coercive measures. The score ranges from 0-5, with higher scores corresponding to better IPR protection. We choose this index for its continuity, comparability, wide coverage and relative completeness. Some basic tabulation based on the index reveals that 1) almost all countries strengthen IPR protection over the sample period; 2) high-income countries have better IPRs protection, but the relationship is highly non-linear. The non-linearity allows us to identify the effects of imports separately from countries with different IPRs.

We construct two import competition variables based on the index: High IPR Competition and Low IPR Competition and substitute them for waged based import competition. The results, available upon request from the authors, indicate that the effects of import competition broken down by IPR protection are different from the import competition broken down by wages. Import competition from High IPR countries stimulates the U.S. firm R&D expenditures, but does not improve firms' patent and citations. This result stands in contrast to our findings that when confronting HWC import competition, U.S. firms increase R&D expenditures, file more patents and receive more citations.

Moreover, we examine the sensitivity of our results by excluding a few countries that could drive much of the U.S. imports. For instance, we check the robustness of the results by excluding the Canada and Mexico from HWC imports and by excluding China from LWC imports and find that our prior conclusions are unaffected. One might worry that import competition can cause sample attrition. In a robustness test, we restrict the sample to a balanced sample of firms that existed throughout the entire sample period and repeat the tests. Reassuringly, the results show that our main conclusions continue to hold.

6. Discussion and Conclusions

This paper investigates the relationship between import competition and innovation. Empirical analyses based on a large sample of U.S. public firms in the manufacturing sector show that firms in industries that have experienced a greater level of import competition from HWCs significantly increase their R&D expenditures and generate a greater number of patents, whereas firms in industries that have experienced a greater level of import competition from LWCs significantly reduce their R&D expenditures and generate fewer patents. We also find heterogeneity in responses from firms of different size, patent stock, and profitability. The increase in innovative activity in response to import competition from HWCs is most pronounced among the largest, most knowledgeable, and most profitable firms, whereas the industry laggards seem to respond in innovative activities in face of import competition from LWCs. Taken together, these findings support our arguments that import competition from HWCs is more like "neck-and-neck" competition, which incentivizes firms, and especially leading firms, to increase innovation effort to stay ahead. In contrast, import competition from LWCs is more like laggard competition, which does not prompt the industry leading firms to innovate.

These findings extend the theoretical debate on the relationship between competition and innovation. They show that capability differences among both incumbent firms and entrants matter for the impact of competition on innovation. By bringing down the level of analysis from the industry level to the firm level, these results deepen our understanding of the heterogeneity among firms' innovation strategies. The results also highlight the circumstances under which existing firms become a source of radical inventions, and under which leading firms enhance their competitive advantages.

The study offers implications for managers as well as policy makers. It highlights a channel through which import competition affects domestic firms' long-term competitiveness or even their survival: by affecting their ability to reinvent themselves to stay ahead of their competition. It suggests that managers should interpret the implications of import competition beyond product market competition and think more strategically about their long-term innovation strategy to stay ahead of the global competition. In addition to monitoring import competition in their own industries, managers need to be aware of the effect of import competition on their suppliers. As firms source more and more of their upstream production to LWCs, they need to keep in mind that their domestic suppliers might be under so much competitive pressure that they give up R&D efforts, impacting their ability to upgrade their supply chains, designs, and processes (The Economist, 2012).

To the extent that innovation drives economic growth, policy makers should be mindful that the openness of trade with different countries will have different impacts on the long-term performance of domestic firms and on the long-term prospect of the domestic economy. While trading with LWCs has brought tremendous benefits to American consumers, it places significant downward pressure on the profitability of U.S. firms and on non-leading firms in particular. Instead of letting them give up innovation entirely, policy makers should design incentives to encourage these firms to embrace innovation that will upgrade their products and processes.

This study has a few limitations that invite future research. First, we do not have detailed data on technological competition from overseas to connect directly with import competition. We use information about inventors' nationality in the USPTO patent database to proxy for technological competition from overseas. Most of these registered "inventors" are corporations headquartered outside U.S. It can be reasonably assumed that, as a foreign firm exports more and more products to U.S., it would apply for USPTO patents to prevent U.S. firms from copying its ideas and the technologies embedded in its products. Therefore, patent applications filed by foreigners at least partially represent the degree of technological competition coming from overseas. It will be interesting to study import competition and technological competition coming from overseas more directly when such data become available. In addition, the measure of import competition is based on industry rather than firm level data. This industry-level measure does not give us accurate information about the competition landscape faced by a particular firm. Future studies can look at firm-level trade shock and innovative activities when such shocks can be identified.

Despite these caveats, this paper connects research on trade, product market competition and innovation. It theorizes and quantifies the relationships between import competition and firm innovation for incumbents of different capabilities using a large sample of firms. The effort will hopefully deepen our understanding of global competition and its impact on firms' innovation strategies.

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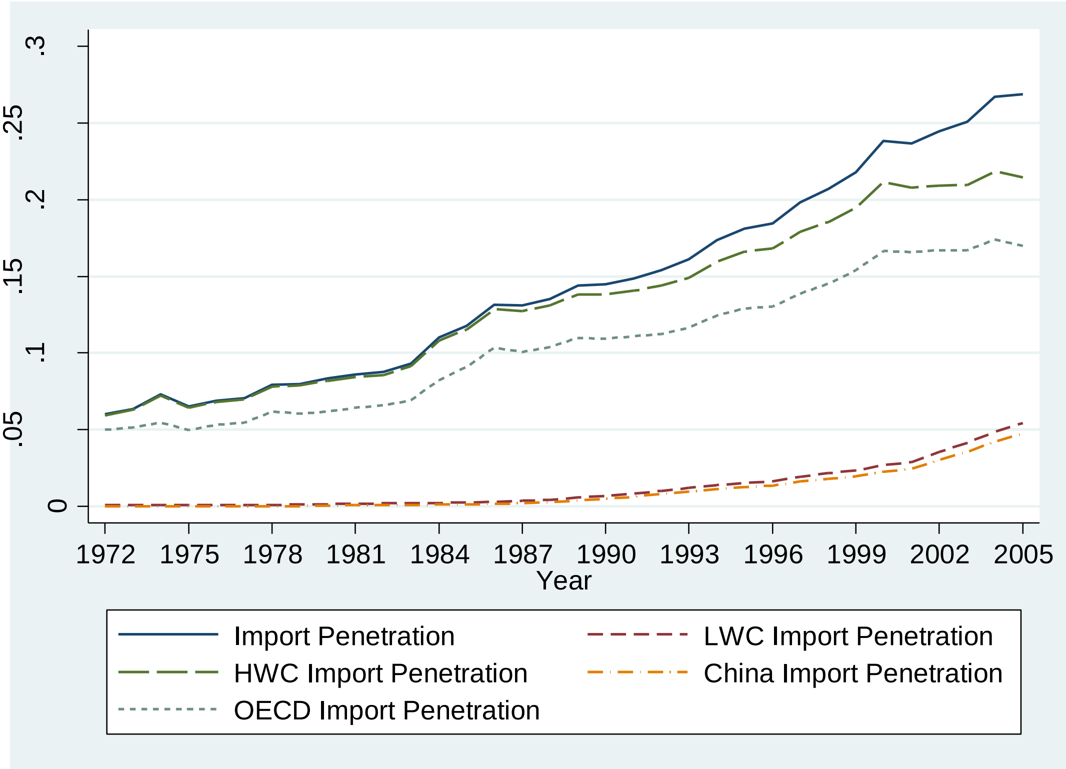
Appendix

List of low-wage countries (LWCs)

Afghanistan	China	India	Pakistan
Albania	Comoros	Kenya	Rwanda
Angola	Congo	Lao PDR	Samoa
Armenia	Equatorial Guinea	Lesotho	Sao Tome
Azerbaijan	Eritrea	Madagascar	Sierra Leone
Bangladesh	Ethiopia	Malawi	Somalia
Benin	Gambia	Maldives	Sri Lanka
Bhutan	Georgia	Mali	St. Vincent
Burkina Faso	Ghana	Mauritania	Sudan
Burundi	Guinea	Moldova	Togo
Cambodia	Guinea-Bissau	Mozambique	Uganda
Central African Rep	Guyana	Nepal	Vietnam
Chad	Haiti	Niger	Yemen

Figure 1

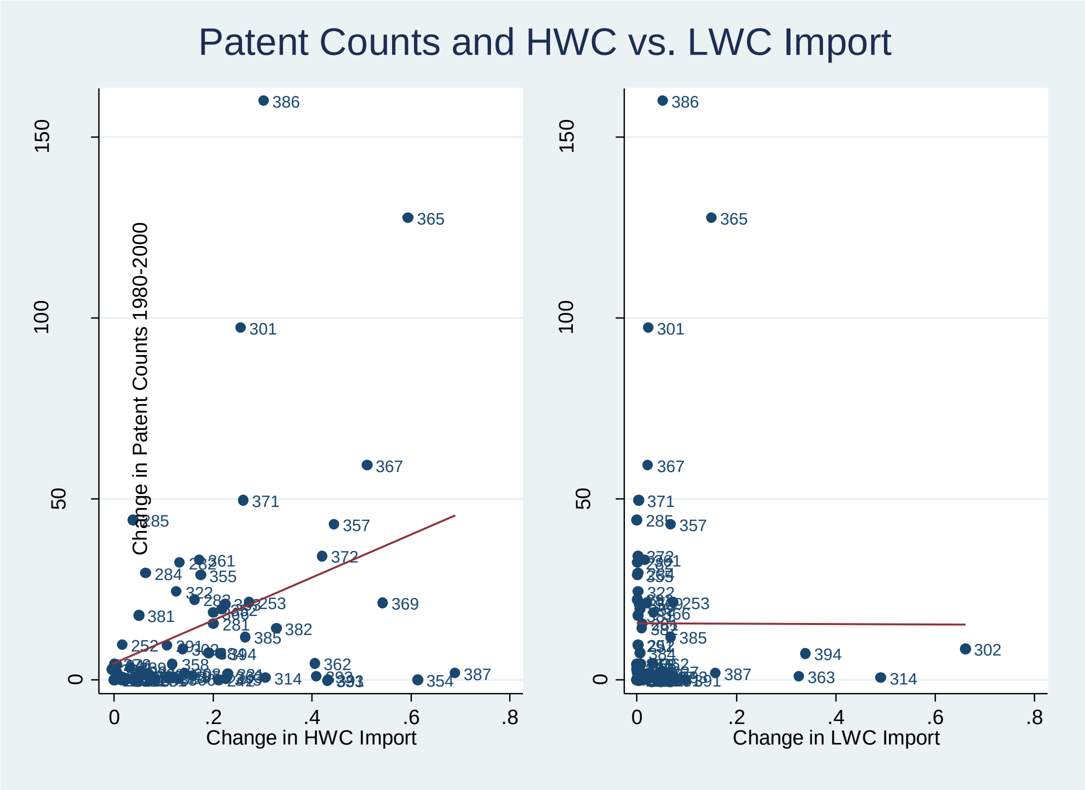
Import competition from different origins



Note: We plot import competition share from different origins over the entire sample period.

Source: International trade data from U.S. Census Bureau.

Figure 2 Scatterplot of changes in number of patent counts versus changes in import shares from LWCs and HWCs, 1980-2000



Note: This figure plots the changes in each industry's average number of patents (Y-axis) against changes in the share of imports from HWCs (X-axis, left panel) and LWCs (X-axis, right panel) over 1980-2000. Each dot represents a three-digit SIC industry data point.

Source: U.S. Census Bureau and USPTO.

Table 1

Summary Statistics

	Mean	SD	Min	Max
R&D Expenditures (in million USDs)	46.231	313.81	0	12183
# Patents	13.08	78.88	0	3128
# Citations	104.85	654.13	0	27964
Assets (in million USDs)	1560.5	10216.4	1	479921
Sales (in million USDs)	1452.0	8769.03	0.001	335086
Cash/Asset	0.183	0.227	0	1
Segment #	1.458	0.961	1	10
Age	11.951	11.619	0	61
Import Competition	0.193	0.326	0	3.078
High-Wage Import Competition	0.178	0.254	0	3.05
Low-Wage Import Competition	0.015	0.095	0	0.915
Industry HHI	0.245	0.181	0.046	0.894

Table 2

Import Competition and Firms' R&D Expenditures

	(1) Ln(R&D)	(2) Ln(R&D)	(3) Ln(R&D)	(4) Ln(R&D)
Import Competition	0.481***			
	(0.112)			
HWC Import Competition		0.710***		0.725***
		(0.119)		(0.118)
LWC Import Competition			-1.229***	-1.293***
			(0.313)	(0.322)
Ln(Sales)	0.491***	0.490***	0.494***	0.492***
	(0.012)	(0.012)	(0.012)	(0.012)
Ln(Age)	-0.057***	-0.056***	-0.059***	-0.056***
	(0.019)	(0.019)	(0.019)	(0.019)
Cash/Asset	2.465***	2.455***	2.490***	2.456***
	(0.071)	(0.071)	(0.071)	(0.071)
Industry HHI	-0.255***	-0.232**	-0.162*	-0.165*
	(0.093)	(0.094)	(0.094)	(0.093)
Ln(Segment#)	0.066	0.068	0.054	0.064
	(0.045)	(0.045)	(0.045)	(0.045)
Industry FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	50,201	50,201	50,201	50,201
R^2	0.555	0.557	0.555	0.558
P value of HWC-LWC				0.001

***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels. Standard errors are clustered at the firm level. All independent variables are lagged by three years.

Table 3

Import Competition and Firms' Patent Counts

	(1) Ln(Patents)	(2) Ln(Patents)	(3) Ln(Patents)	(4) Ln(Patents)
Import Competition	0.446***			
	(0.112)			
HWC Import Competition		0.523***		0.526***
		(0.122)		(0.121)
LWC Import Competition			-0.151	-0.230
			(0.275)	(0.284)
Ln(Sales)	0.361***	0.361***	0.363***	0.361***
	(0.014)	(0.014)	(0.014)	(0.014)
Ln(Age)	0.013	0.013	0.011	0.013
	(0.018)	(0.017)	(0.018)	(0.017)
Cash/Asset	1.560***	1.556***	1.579***	1.556***
	(0.077)	(0.077)	(0.078)	(0.077)
Industry HHI	-0.064	-0.046	-0.036	-0.036
	(0.103)	(0.104)	(0.104)	(0.104)
Ln(Segment#)	0.070	0.070	0.061	0.069
	(0.045)	(0.045)	(0.045)	(0.045)
Industry FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	49,049	49,049	49,049	49,049
R^2	0.367	0.367	0.365	0.367
P value of HWC-LWC				0.015

***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels. Standard errors are clustered at the firm level. All independent variables are lagged by three years.

Table 4

Import Competition and Firms' Patent Citations

	(1) Ln(Cites)	(2) Ln(Cites)	(3) Ln(Cites)	(4) Ln(Cites)
Import Competition	0.501***			
	(0.156)			
HWC Import Competition		0.568***		0.569***
		(0.172)		(0.171)
LWC Import Competition			0.020	-0.065
			(0.308)	(0.315)
Ln(Sales)	0.487***	0.487***	0.489***	0.487***
	(0.018)	(0.018)	(0.018)	(0.018)
Ln(Age)	0.020	0.020	0.017	0.020
	(0.025)	(0.025)	(0.025)	(0.025)
Cash/Asset	2.126***	2.123***	2.147***	2.123***
	(0.111)	(0.111)	(0.111)	(0.111)
Industry HHI	-0.088	-0.067	-0.064	-0.064
	(0.154)	(0.154)	(0.156)	(0.156)
Ln(Segment#)	0.090	0.090	0.080	0.090
	(0.065)	(0.065)	(0.065)	(0.065)
Industry FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	49,049	49,049	49,049	49,049
R^2	0.325	0.325	0.324	0.325
P value of HWC-LWC				0.077

***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels. Standard errors are clustered at the firm level. All independent variables are lagged by three years.

Table 5

Import Competition and Patent Novelty

	(1)	(2)	(3)	(4)
	Ln(Breakthrough Patents)			
Import Competition	0.131***			
	(0.031)			
HWC Import Competition		0.159***		0.161***
		(0.036)		(0.036)
LWC Import Competition			-0.088**	-0.112***
			(0.040)	(0.042)
Ln(Sales)	0.041***	0.041***	0.041***	0.041***
	(0.004)	(0.004)	(0.004)	(0.004)
Ln(Age)	0.000	0.000	-0.000	0.000
	(0.004)	(0.004)	(0.004)	(0.004)
Cash/Asset	0.158***	0.157***	0.164***	0.157***
	(0.018)	(0.018)	(0.019)	(0.018)
Industry HHI	-0.034	-0.028	-0.024	-0.024
	(0.025)	(0.024)	(0.024)	(0.024)
Ln(Segment#)	-0.020*	-0.020*	-0.023*	-0.020*
	(0.012)	(0.012)	(0.012)	(0.012)
Industry FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	49,049	49,049	49,049	49,049
R^2	0.090	0.091	0.087	0.091
P value of HWC-LWC				0.001

***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels. Standard errors are clustered at the firm level. All independent variables are lagged by three years.

Table 6

Heterogeneous Responses to Import Competition: Leader versus Laggard

	(1)	(2)	(3)	(4)	(5)	(6)
	Ln(R&D)	Ln(Patents)	Ln(R&D)	Ln(Patents)	Ln(R&D)	Ln(Patents)
	Leader by sales		Leader by patent stock		Leader by profit margin	
HWC Import Competition	0.909***	0.431***	0.743***	0.230**	0.646***	0.494***
	(0.150)	(0.122)	(0.170)	(0.111)	(0.165)	(0.154)
LWC Import Competition	-0.572*	0.274	-1.648***	0.919**	-1.918***	-0.271
	(0.321)	(0.242)	(0.603)	(0.426)	(0.384)	(0.299)
HWC Import Competition	0.886***	1.010***	0.724***	0.691***	0.371*	0.326
*Leader	(0.338)	(0.316)	(0.215)	(0.228)	(0.203)	(0.215)
LWC Import Competition	-1.290	-0.441	-0.077	-1.445***	0.371	-0.085
*Leader	(1.166)	(0.803)	(0.591)	(0.398)	(0.685)	(0.500)
Leader Dummy	1.470***	0.992***	0.529***	0.882***	0.226***	0.117**
	(0.072)	(0.067)	(0.057)	(0.053)	(0.046)	(0.047)
HWC Import Competition	-1.226***	-0.521***	-0.139***	-0.395***	-0.196	-0.271
*Laggard	(0.142)	(0.110)	(0.051)	(0.035)	(0.200)	(0.176)
LWC Import Competition	0.850**	0.701**	-0.623***	-0.001	0.378	0.374
*Laggard	(0.399)	(0.312)	(0.175)	(0.116)	(0.603)	(0.440)
Laggard Dummy	-0.347***	-0.181***	0.661	-0.223	-0.020	0.038
	(0.033)	(0.026)	(0.638)	(0.465)	(0.043)	(0.039)
Ln(Sales)			0.462***	0.268***	0.515***	0.358***
			(0.014)	(0.012)	(0.014)	(0.014)
Ln(Age)	-0.006	0.098***	-0.252***	-0.190***	-0.112***	0.017
	(0.024)	(0.020)	(0.020)	(0.014)	(0.020)	(0.017)
Cash/Asset	1.751***	0.958***	2.239***	1.064***	2.508***	1.513***
	(0.083)	(0.076)	(0.077)	(0.062)	(0.082)	(0.077)
Industry HHI	-0.210*	-0.144	-0.076	-0.025	-0.061	-0.020
	(0.120)	(0.114)	(0.098)	(0.090)	(0.099)	(0.103)
Ln(Segment#)	0.272***	0.239***	0.024	0.036	0.067	0.086*
	(0.058)	(0.051)	(0.047)	(0.038)	(0.048)	(0.044)
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	50,201	49,049	50,201	49,049	50,201	49,049
R^2	0.467	0.292	0.594	0.484	0.568	0.371
P value of HWC-LWC	0.000	0.551	0.0001	0.128	0.000	0.024

***, **, and * indicate statistical significance at the 1%, 5%, and 10% level. Standard errors are clustered at the firm level. All independent variables are lagged by three years. Leader (laggard) refers to firms in the top (bottom) tercile among its industry peers in terms of (1) sales, (2) patent stock, and (3) profitability.

Table 7

Import Competition and Innovation: Controlling for Industry Life Cycle Dynamics

	(1) Ln(R&D)	(2) Ln(Patents)	(3) Ln(Cites)	(4) Ln(Breakthroughs)
HWC Import Competition	0.903***	0.574***	0.913***	0.144***
	(0.157)	(0.055)	(0.078)	(0.014)
LWC Import Competition	-1.242**	-0.087	-0.360	-0.280***
	(0.618)	(0.171)	(0.237)	(0.039)
Ln(Sales)	0.544***	0.369***	0.497***	0.042***
	(0.014)	(0.004)	(0.005)	(0.001)
Ln(Age)	-0.107***	0.020***	0.036***	0.004**
	(0.019)	(0.007)	(0.011)	(0.002)
Cash/Asset	2.089***	1.359***	1.905***	0.134***
	(0.080)	(0.030)	(0.048)	(0.007)
Industry HHI	-0.010	-0.056	-0.050	0.002
	(0.105)	(0.039)	(0.065)	(0.010)
Ln(Segment#)	0.072	0.078***	0.112***	-0.015***
	(0.046)	(0.014)	(0.022)	(0.004)
Industry*Year FE	Yes	Yes	Yes	Yes
Observations	50,201	49,049	49,049	49,049
R^2	0.612	0.394	0.355	0.117
P value of HWC-LWC	0.0008	0.0003	0.0000	0.0000

***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels. Standard errors are clustered at the firm level. All independent variables are lagged by three years.

Table 8

Import Competition and Innovation: Controlling for Technological Competition

	(1) Ln(R&D)	(2) Ln(Patents)	(3) Ln(Cites)	(4) Ln(Breakthroughs)
HWC Import Competition	0.266***	0.103*	-0.007	0.065***
	(0.103)	(0.058)	(0.085)	(0.013)
LWC Import Competition	-1.305***	-0.103	0.206	-0.002
	(0.292)	(0.131)	(0.212)	(0.030)
HWC Technological Competition	2.872***	39.993***	33.761***	3.301**
	(0.925)	(5.122)	(7.279)	(1.453)
LWC Technological Competition	-0.234**	0.096	-0.238	-0.083***
	(0.099)	(0.097)	(0.159)	(0.026)
Ln(Sales)	0.534***	0.362***	0.481***	0.042***
	(0.013)	(0.004)	(0.006)	(0.001)
Ln(Age)	-0.087***	0.028***	0.040***	0.005***
	(0.019)	(0.007)	(0.011)	(0.002)
Cash/Asset	1.964***	1.302***	1.734***	0.107***
	(0.078)	(0.031)	(0.049)	(0.007)
Industry HHI	-0.251**	-0.001	0.319***	0.068***
	(0.103)	(0.052)	(0.084)	(0.013)
Ln(Segment#)	0.077*	0.094***	0.139***	-0.012***
	(0.046)	(0.014)	(0.022)	(0.004)
Industry FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	49,043	44,562	44,562	44,562
R^2	0.407	0.406	0.362	0.122
P value of HWC-LWC	0.000	0.14	0.34	0.04

***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels. Standard errors are clustered at the firm level. All independent variables are lagged by three years.

Table 9

Import Competition and Innovation: 2SLS regression

	(1) Ln(R&D)	(2) Ln(Patents)	(3) Ln(Cites)	(4) Ln(Breakthroughs)
HWC Import Competition	1.528*	1.604**	2.129**	0.446**
	(0.788)	(0.683)	(0.875)	(0.173)
LWC Import Competition	-2.388***	-0.495	-1.150**	-0.269**
	(0.597)	(0.463)	(0.540)	(0.109)
Ln(Sales)	0.527***	0.331***	0.370***	0.037***
	(0.013)	(0.013)	(0.015)	(0.004)
Ln(Age)	-0.058**	0.061***	0.076***	0.007
	(0.024)	(0.022)	(0.027)	(0.005)
Cash/Asset	2.758***	1.594***	2.015***	0.165***
	(0.080)	(0.076)	(0.098)	(0.019)
Industry HHI	-0.272**	-0.163	-0.251*	-0.073***
	(0.137)	(0.126)	(0.151)	(0.027)
Ln(Segment#)	0.259***	0.147**	0.146**	-0.005
	(0.068)	(0.061)	(0.073)	(0.017)
Industry FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	25,971	25,971	25,971	25,971
R^2	0.551	0.343	0.311	0.090
P value of HWC-LWC	0.000	0.009	0.001	0.002

***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels. Standard errors are clustered at the firm level. All independent variables are lagged by three years.

Table 10

Import Competition and Innovation: Controlling for International R&D Alliances

	(1) Ln(R&D)	(2) Ln(Patents)	(3) Ln(Cites)	(4) Ln(Breakthroughs)
HWC Import Competition	0.615***	0.455***	0.448***	0.142***
	(0.135)	(0.046)	(0.065)	(0.013)
LWC Import Competition	-1.430***	-0.162	-0.048	-0.117***
	(0.433)	(0.120)	(0.166)	(0.019)
R&D Alliances with HWC Partners	0.754***	0.918***	1.185***	0.236***
	(0.052)	(0.047)	(0.062)	(0.029)
R&D Alliances with LWC Partners	0.729**	0.775***	0.373	0.185*
	(0.293)	(0.273)	(0.228)	(0.099)
Ln(Sales)	0.529***	0.346***	0.441***	0.038***
	(0.014)	(0.004)	(0.006)	(0.001)
Ln(Age)	-0.111***	0.020***	0.033***	0.001
	(0.021)	(0.008)	(0.012)	(0.002)
Cash/Asset	2.615***	1.521***	2.021***	0.145***
	(0.082)	(0.032)	(0.049)	(0.008)
Industry HHI	-0.130	-0.017	-0.040	-0.042***
	(0.114)	(0.038)	(0.061)	(0.010)
Ln(Segment#)	0.093*	0.085***	0.084***	-0.018***
	(0.056)	(0.017)	(0.026)	(0.005)
Industry FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	36,245	36,245	36,245	36,245
R^2	0.559	0.375	0.331	0.111
P value of HWC-LWC	0.0000	0.069	0.211	0.0000

***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels. Standard errors are clustered at the firm level. All independent variables are lagged by three years.

Table 11

Import Competition and Innovation: Controlling for Export Orientation

	(1) Ln(R&D)	(2) Ln(Patents)	(3) Ln(Cites)	(4) Ln(Breakthroughs)
HWC Import Competition	0.322***	0.402**	0.583**	0.070*
	(0.118)	(0.157)	(0.229)	(0.041)
LWC Import Competition	-1.477***	-0.093	0.072	-0.162***
	(0.293)	(0.265)	(0.314)	(0.048)
HWC Export Orientation	0.256	0.854***	1.166***	0.306***
	(0.209)	(0.259)	(0.354)	(0.072)
LWC Export Orientation	-5.381**	-8.572***	-16.913***	-2.428***
	(2.288)	(2.902)	(3.918)	(0.804)
Ln(Sales)	0.528***	0.368***	0.497***	0.043***
	(0.013)	(0.014)	(0.018)	(0.004)
Ln(Age)	-0.093***	0.021	0.034	0.003
	(0.019)	(0.017)	(0.025)	(0.004)
Cash/Asset	1.951***	1.384***	1.873***	0.122***
	(0.078)	(0.076)	(0.110)	(0.017)
Industry HHI	-0.296***	-0.070	-0.015	0.014
	(0.100)	(0.109)	(0.173)	(0.024)
Ln(Segment#)	0.078*	0.083*	0.116*	-0.014
	(0.044)	(0.043)	(0.063)	(0.011)
Industry FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	50,201	49,049	49,049	49,049
R^2	0.628	0.389	0.346	0.110
P value of HWC-LWC	0.001	0.08	0.149	0.0002

***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels. Standard errors are clustered at the firm level. All independent variables are lagged by three years.

Table 12

Import Competition and Innovation: Excluding Intrafirm Imports

	(1) Ln(R&D)	(2) Ln(Patents)	(3) Ln(Cites)	(4) Ln(Breakthroughs)	(5) Ln(R&D)	(6) Ln(Patents)	(7) Ln(Cites)	(8) Ln(Breakthroughs)
HWC Import Competition	2.528***	1.043***	0.175**	0.013	0.588***	0.314**	0.266	0.099***
Excluding Intrafirm Imports	(0.436)	(0.293)	(0.082)	(0.012)	(0.164)	(0.135)	(0.187)	(0.031)
LWC Import Competition	-5.966**	-1.526	-0.100	-0.072	-1.405***	-0.155	0.001	-0.090**
Excluding Intrafirm Imports	(2.630)	(1.016)	(0.365)	(0.091)	(0.404)	(0.282)	(0.316)	(0.040)
Ln(Sales)	0.555***	0.170***	0.015***	0.002**	0.524***	0.363***	0.489***	0.041***
	(0.022)	(0.012)	(0.003)	(0.001)	(0.014)	(0.014)	(0.018)	(0.004)
Ln(Age)	-0.151***	0.000	-0.002	0.002	-0.122***	0.011	0.018	-0.000
	(0.049)	(0.028)	(0.007)	(0.002)	(0.020)	(0.018)	(0.025)	(0.004)
Cash/Asset	2.692***	0.511***	0.037**	0.007*	2.592***	1.574***	2.143***	0.162***
	(0.171)	(0.082)	(0.018)	(0.004)	(0.082)	(0.077)	(0.111)	(0.019)
Industry HHI	-0.692***	0.038	0.033	-0.007	-0.107	-0.045	-0.070	-0.027
	(0.265)	(0.163)	(0.050)	(0.007)	(0.101)	(0.104)	(0.156)	(0.024)
Ln(Segment#)	0.212*	0.145*	0.032	-0.003	0.031	0.063	0.082	-0.022*
	(0.118)	(0.080)	(0.023)	(0.005)	(0.049)	(0.045)	(0.065)	(0.012)
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2,514	2,422	2,422	2,422	50,201	49,049	49,049	49,049
R^2	0.592	0.297	0.077	0.031	0.559	0.366	0.324	0.088
P value of HWC-LWC	0.001	0.001	0.01	0.372	0.001	0.031	0.463	0.001

***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels. Standard errors are clustered at the firm level. All independent variables are lagged by three years. The first four columns use Census post-2002 related party trade information and the last four columns use the Census post-2002 related party trade information to estimate prior years.

Table 13

Import Competition and Patent Citations: Cross-sectional Heterogeneity according to Industry R&D Intensity

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Ln(R&D)		Ln(Patents)		Ln(Cites)		Ln(Breakthroughs)	
	High-Tech	Low-Tech	High-Tech	Low-Tech	High-Tech	Low-Tech	High-Tech	Low-Tech
HWC Import Competition	1.042***	0.606***	0.866***	0.333***	0.880***	0.409**	0.286***	0.083***
	(0.203)	(0.156)	(0.210)	(0.127)	(0.286)	(0.185)	(0.074)	(0.028)
LWC Import Competition	-8.749***	-0.487	-3.716***	0.225	-5.200***	0.300	-0.898***	-0.098***
	(1.264)	(0.375)	(1.189)	(0.271)	(1.278)	(0.290)	(0.344)	(0.030)
Ln(Sales)	0.566***	0.499***	0.385***	0.346***	0.466***	0.504***	0.043***	0.037***
	(0.017)	(0.019)	(0.018)	(0.017)	(0.022)	(0.023)	(0.006)	(0.004)
Ln(Age)	-0.157***	-0.092***	0.004	0.023	0.010	0.039	0.009	-0.005
	(0.029)	(0.026)	(0.028)	(0.020)	(0.039)	(0.031)	(0.007)	(0.004)
Cash/Asset	2.686***	2.059***	1.750***	1.064***	2.223***	1.626***	0.158***	0.198***
	(0.091)	(0.132)	(0.093)	(0.114)	(0.127)	(0.180)	(0.022)	(0.032)
Industry HHI	-0.140	0.117	-0.206	0.130	-0.330	0.156	-0.053	-0.009
	(0.165)	(0.115)	(0.173)	(0.116)	(0.252)	(0.175)	(0.039)	(0.024)
Ln(Segment#)	0.028	0.056	0.100	0.060	0.097	0.069	-0.019	-0.018
	(0.083)	(0.056)	(0.088)	(0.048)	(0.121)	(0.071)	(0.025)	(0.011)
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	18,855	31,346	18,855	30,194	18,855	30,194	18,855	30,194
R^2	0.551	0.533	0.356	0.374	0.307	0.342	0.098	0.096
P value of HWC-LWC	0	0.007	0.001	0.716	0.001	0.746	0.002	0.001

***, **, and * indicate statistical significance at the 1%, 5%, and 10% level. Standard errors are clustered at the firm level. All independent variables are lagged by three years. High-Tech (Low-Tech) refers to an industry whose median firm's R&D expenditures divided by assets is over (less than) 5%.

Table 14
Import Competition and Patent Citations: Cross-sectional Heterogeneity according to MNCs

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Ln(R&D)		Ln(Patents)		Ln(Cites)		Ln(Breakthroughs)	
	MNC=1	MNC=0	MNC=1	MNC=0	MNC=1	MNC=0	MNC=1	MNC=0
HWC Import Competition	0.567***	0.536***	0.693***	0.273**	0.741***	0.329**	0.216***	0.100***
	(0.188)	(0.137)	(0.186)	(0.111)	(0.254)	(0.154)	(0.059)	(0.033)
LWC Import Competition	-1.759***	-1.444***	-0.027	-0.380*	0.143	-0.120	-0.151*	-0.041
	(0.675)	(0.271)	(0.433)	(0.202)	(0.519)	(0.316)	(0.088)	(0.036)
Ln(Sales)	0.783***	0.400***	0.582***	0.271***	0.716***	0.385***	0.083***	0.027***
	(0.022)	(0.015)	(0.024)	(0.014)	(0.031)	(0.018)	(0.009)	(0.003)
Ln(Age)	-0.114***	-0.165***	0.079**	-0.047***	0.100*	-0.061**	0.014	-0.009**
	(0.037)	(0.020)	(0.037)	(0.016)	(0.052)	(0.025)	(0.009)	(0.003)
Cash/Asset	3.214***	2.317***	1.984***	1.370***	2.413***	1.921***	0.311***	0.103***
	(0.151)	(0.082)	(0.157)	(0.074)	(0.221)	(0.111)	(0.048)	(0.014)
Industry HHI	-0.523***	0.031	-0.274	0.001	-0.470	0.011	-0.150***	0.016
	(0.192)	(0.084)	(0.218)	(0.083)	(0.313)	(0.134)	(0.055)	(0.019)
Ln(Segment#)	-0.220***	0.101**	-0.099	0.085**	-0.169	0.124**	-0.041*	-0.018**
	(0.074)	(0.049)	(0.074)	(0.041)	(0.107)	(0.061)	(0.024)	(0.009)
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	13,240	36,961	13,240	35,809	13,240	35,809	13,240	35,809
R^2	0.620	0.483	0.440	0.292	0.424	0.254	0.143	0.062
P value of HWC-LWC	0.001	0.001	0.134	0.006	0.306	0.233	0.001	0.019

***, **, and * indicate statistical significance at the 1%, 5%, and 10% level. Standard errors are clustered at the firm level. All independent variables are lagged by three years. MNC refers to a dummy variable indicating multinational firms whose foreign income accounts for over 1% of firm sales.

Table 15
Granger Causality Test at the Industry Level

	(1) HWC Import Competition	(2) LWC Import Competition
L1.Ln(Patents)	-0.007	0.001
	(0.032)	(0.013)
L2. Ln(Patents)	-0.004	-0.001
	(0.037)	(0.015)
L3. Ln(Patents)	0.007	-0.001
	(0.037)	(0.015)
L4. Ln(Patents)	-0.001	-0.001
	(0.033)	(0.013)
L1.Import Competition	0.009	0.005
	(0.018)	(0.018)
L2.Import Competition	0.631***	1.725***
	(0.160)	(0.326)
L3.Import Competition	0.132	-0.281
	(0.195)	(0.496)
L4.Import Competition	0.243	-0.379
	(0.191)	(0.378)
Observations	3,261	3,261
R-squared	0.076	0.135
Joint F Test L1-L4.Ln(Patents)=0 P value	0.97	0.98

***, **, and * indicate statistical significance at the 1%, 5%, and 10% level. The last row reports the F-statistic for testing jointly all four lags of Ln(Patents) coefficients are equal to zero.