Competitive Pressure, Innovation, and Trade Protection:
Evidence from U.S. Patent Data

Benjamin H. Liebman* (St. Josephs University)
and
Kara M. Reynolds** (American University)

February 2018

ABSTRACT

Recent theoretical models have suggested that the relationship between competition and innovation may best be characterized as an inverted-U shape: firms in industries with low levels of competition are more likely to innovate in the wake of increased competition as they attempt to escape competition, while those in highly competitive industries will decrease innovation in the wake of increased competition as the profit incentive to innovate dissipates. Results from other studies have found positive as well as negative relationships between innovation and competition. In a parallel literature, trade economists have produced conflicting results regarding the impact of trade liberalization on innovation. One stream of research has shown that increased access to imported intermediate goods increases productivity, suggesting a positive relationship between imports and innovation. Others have hypothesized that firms may use the technology embodied in intermediate inputs as a substitute for domestic innovation. In this paper, we merge these divergent literatures and investigate whether innovation, as measured by the production of patents by US manufacturers, has been impacted by market competition and tariff reductions. Our empirical findings indicate that insulation from imports in the form of higher tariffs on final goods was associated with innovation until the late 1980s, while falling tariffs on intermediate goods appears to have facilitated innovation during the 1990s. We also find evidence of the inverted u-shaped relationship between market competition and innovation.

JEL Codes: F13

Key Terms: Patents, strategic trade protection

* St. Joseph's University. Department of Economics, Philadelphia, PA 19131. Telephone: (610) 660-1553. E-mail: bliebman@sju.edu.

** Corresponding Author: American University, Department of Economics, 4400 Massachusetts Avenue, NW, Washington, DC 20016. Telephone: (202) 885-3768. E-mail: Reynolds@american.edu.

I. Introduction

Innovation has long been recognized by economists as a major determinant of economic growth, a link that has been established in both the empirical and theoretical literature. As a result, it is natural that economists continue to be interested in what determines industrial innovation, particularly because neither the theory nor the empirical evidence has been quite as clear on this question. For example, one strain of literature investigates the relationship between innovation and the level of competition in an industry, whether domestic or foreign; theories as early as Schumpeter (1942) hypothesize that firms will invest less as the level of competition increases (thus reducing the returns on this investment). However, empirical evidence in such papers as Nickell (1996) instead suggest a positive relationship between the two variables. In the face of this conflicting evidence, Aghion et al. (2005) develop a model and show some empirical evidence that the relationship between competition and innovation may instead be characterized as an inverted-U: innovation initially increases with the level of competition, but eventually starts to decrease.

Subsequent empirical studies such as Hashmi (2013) found less evidence of this inverted U - shape relationship between innovation and competition. Hashmi (2013) hypothesizes that the failure of this relationship to hold in a sample of US industries may be because US industries are more likely to have firms that are the technological leaders in their field when compared to their UK counterparts.

However, neither Aghion et al. (2005) or Hashmi (2013) directly incorporate trade variables such as import penetration and tariffs into their analyses, thus failing to allow for the possibility that increasing globalization could result in a very different relationship between competition and firm investment in R&D. Lower trade barriers have provided domestic firms with alternative methods to become more competitive other than such investment, including incorporating less expensive or more technologically advanced intermediate inputs into their production process.

As illustrated in Figure (1), U.S. industries are increasingly using imported intermediate inputs in their production processes. OECD data reports that the percentage of intermediate inputs imported by U.S. manufacturing industries increased from 14 percent in the mid-1990s to 21 percent just 10 years later. Some of these imports were previously supplied by upstream US firms. Others were produced internally by the firm itself. This use of imported intermediate inputs varies widely across US industries; while the information and communication technology sectors (ISIC sectors 30, 32, and 33) now imports over half of their intermediate inputs, those in what the OECD classifies as low and medium-low technology sectors (ISIC sectors 15-23, 36-37) imports just 16 percent of their intermediate imports. The growth in outsourcing to foreign suppliers is undoubtedly driven, in part, by the steady decline in US tariff rates on imported inputs, which is illustrated in Figure 2.

In general, the theoretical impact of imports on innovation is somewhat ambiguous. It could stifle innovation if domestic firms believe that the additional source of competition provided by foreign firms sufficiently undermines future profits and the likelihood to recoup the substantial cost of investment. On the other hand, competition from foreign firms could stimulate innovation if it pressures domestic firms to become more efficient in order to survive. Access to cheaper foreign intermediate goods may increase profits of domestic firms, thereby providing the additional funding and positive expectations necessary to undertake R&D spending, but this access to the R&D imbedded in imported intermediate goods may reduce the incentive for firms to perform their own R&D.

Recent empirical studies, including Amiti and Konings (2007) and Goldberg et al. (2010), find evidence that lower tariffs on intermediate inputs generates significant gains in productivity and product innovation. Amiti and Konings (2007) use Indonesian manufacturing census data to show that input tariff reductions lead to productivity gains that are at least twice as high as productivity gains stemming from reducing output tariffs. Goldberg et al. (2010) find that lower input tariffs account on average for almost a third of the new products introduced by domestic firms, primarily due to increased access to new input varieties that were unavailable prior to the trade liberalization.

In this study, we investigate the relationship between competition, both foreign and domestic, and innovation, where innovation is measured in the form of patent production by US manufacturers. To our knowledge, very few previous studies have studied the relationship between tariffs and innovation as measured by patent production. Im et al. (2015) finds evidence of an inverted U-shaped relationship between competition and the market value of patents and use tariff cut events as a quasi-natural experiment to investigate how the value of innovation is impacted by a (seemingly) exogenous increase in competition. They find that reducing tariffs stimulates the value of innovation in industries where market competition is mild but reduce the value of innovation in industries where competition is severe. This provides additional evidence of the inverted U-shaped hypothesis.

The closest paper to our study is probably Liu and Qiu (2016), who investigate the impact of tariff reductions in intermediate goods on patents. They also control for the degree of market competition by including an HHI variable in their empirical tests, which they find insignificant. However, unlike our paper, they do not incorporate more complicated aspects of competition, such as a quadratic term to test the inverted u-shaped relationship, or how this shape is altered when there is a technology gap among member firms, all of which is central to Aghion et al. (2006) and Hashmi (2013).

In the paper that follows, we combine several elements of the previous literature. Like Aghion et al. (2006) and Hashmi (2013), we study the relationship between competition and citation-weighted patents. However, unlike these papers, we incorporate the effect of trade flows and tariffs on innovation output. As suggested by the literature above, increasing exposure to global markets is certainly one component of the market competition facing domestic firms, but this internationalization uniquely impacts investment decisions as firms may choose to outsource or import intermediate inputs instead of investing in R&D. Therefore, failure to include these measures of globalization in an empirical model that measures the impact of competition on innovation could result in severe omitted variable bias in the resulting estimates.

Therefore, building on work by Amiti and Konings (2007) and Goldberg et al. (2010), we include in our model both tariffs on final goods and tariffs on intermediate goods, comparing the relative impact of the two measures on innovation. And like Im et al. (2015), we study the impact of tariffs, but control for the magnitude of tariffs as well as whether the tariffs cover final or intermediate goods.

We are interested not just in the impact of these trade variables on innovation, but how the inclusion of these variables may alter the empirical estimates the relationship between competition and innovation, as tested by Aghion et al. (2005) and others. More specifically, we are curious whether there is still evidence of the inverted u-shape relationship between competition and citation-weighted patents even after trade variable are added to the model. Figure 3 plots citation-weighted patents against both tariffs on both final goods and intermediate goods. While there is an apparent downward sloping relationship for tariffs on both final goods and inputs, it is evident from figure 3a that there are several industries with very high tariffs on final goods that also have relatively high levels of innovation. This is also evident in figure 4a, which plots the same relationship for the first half of our sample (1975-1987). In contrast, figures 3b and 4b reveal a more clearly negative association between input tariffs and innovation. However, it remains to be seen whether we will find negative and statistically significant relationships between tariffs, both on inputs and final goods, and innovation when our competition variables are included in our empirical model.

The rest of the paper is organized as follows. In section II, we provide a brief review of the theoretical and empirical literature on the relationship between innovation and competition, and how the growing use of outsourcing could change this relationship. Section III provides an overview of the data and empirical methodology used in the study, and Section IV discusses the results. We conclude in Section V and propose some avenues for further research.

II. Innovation and Imports: Substitutes or Complements?

As alluded to above, Aghion et al. (2005) derive a theoretical model to explain why there might be an inverted-U relationship between innovation and competition. At any point in time in this model there are two types of sectors in the economy: (1) a "neck-and-neck" sector in which both firms are on a technological par; and (2) an "unleveled" sector in which one firm (known as the leader) is a step ahead of its laggard competitor, and is thus able to produce at a lower cost and earn a higher profit. The authors show that in the neck-and-neck industry, the level of research intensity increases as the level of market competition increases. Aghion et al. (2005) refer to this as the “escape competition” effect—firms continuously innovate because the incremental profits from being the leader are higher in less competitive industries which have a higher mark-up.[1] In contrast, in the unleveled sector the level of research intensity decreases with competition. This is sometimes known as the classic Schumpeterian effect (Schumpeterian 1942); intuitively, with more competition, the rents or profits from catching up to the leader fall, thus firms have less incentive to innovate.

Consider the aggregate relationship between competition and innovation under this model. At low levels of competition, firms within the neck-and-neck sectors have little incentive to innovate because profit levels are already so high; on the other hand, laggard firms in the unleveled sector have an extremely high incentive to innovate in order to catch up to the leader. Sectors at low levels of competition will thus spend most of their time as neck-and-neck sectors.

At very high levels of competition the opposite holds true: because of low profit levels, laggard firms have little incentive to innovate in unleveled sectors but firms in the neck-and-neck sectors have a high incentive to innovate in order to reap the gain in profits. Sectors at high levels of competition will thus spend most of their time as unleveled sectors in which innovation decreases with competition. This results in the overall U-shaped relationship between competition and innovation.

Aghion et al. (2005) test this relationship on a sample of 311 firms listed on the London Stock Exchange between 1973 and 1994; the firms were aggregated into 17 industries (using two-digit Standard Industrial Classification (SIC) codes). On average, they find strong statistical evidence that there is an inverted-U relationship between innovation and competition. Moreover, their results suggest that neck-and-neck industries exhibit a steeper inverted-U relationship between innovation and competition than unleveled industries, a finding they note is consistent with their theoretical predictions.

The results from empirical tests of the relationship between innovation and competition in other samples have produced mixed results. For example, Hashmi (2011) tests the same theoretical model using a sample of over 7,000 publicly traded US firms over the period 1976 through 2001. The author aggregates these firms into industries, testing the model using both 116 three-digit SIC and 20 two-digit SIC manufacturing industries. Rather than an inverted-U relationship, Hashmi (2013) finds that on aggregate the U.S. data exhibits a negative relationship between competition and innovation, even when allowing for a non-linear relationship between the two variables, and that the relationship between the two variables is statistically identical when you compare neck-and-neck and unleveled industries. The author develops a theoretical model to show that the empirical results from the two papers are not necessarily inconsistent if UK manufacturing industries are more neck-and-neck when compared to their U.S. counterparts. Interestingly, Correa and Ornaghi (2014) reached nearly the opposite conclusion using a sample

[1] This escape competition effect had previously been hypothesized by researchers such as Nickell (1996).

of 223 four-digit SIC industries over the period 1974 to 2001—namely a positive and nearly monotonic relationship between competition and innovation.[2]

Although all of these papers recognize imports as a potential source of competition (for example, Hashmi (2013) uses a weighted exchange rate as an instrument for competition while Correa and Ornaghi (2014) use a variety of tariff measures for their instrument), this literature has for the most part moved forward separately from the rich literature on the relationship between trade and innovation.[3] Much like the ambiguity suggested by the inverted-U shape relationship described above, trade economists have derived models suggesting that the link between import competition and innovation can either be increasing (as in Ederington and MacCalman (2008) and Grossman and Helpman (1991b)) or decreasing (as in Rodrik (1992)). Empirical studies on the relationship between import competition and innovation have typically found that an increase in import competition results in higher investment in R&D and innovation.[4,5]

Of more interest to our work is the literature that studies the degree to which imports, and particularly imported intermediate inputs, can be used as a substitute for innovation by the firm. As discussed above, theoretical models such as Grossman and Helpman (1991b) and Coe and Helpman's (1995) suggest that international technological spillovers may play a large role in aggregate productivity. Recent empirical studies like Amiti and Konings (2007) and Goldberg et al (2010) find that lower tariffs on intermediate inputs results in significant gains in productivity and product innovation, suggesting that a major channel for this technological spillover is through the outsourcing of intermediate inputs. However, there are papers that find that reducing output tariffs also induce productivity gains, including Krishna and Mitra (1998), Sivadasan (2006), and Topalova (2007). For this reason, we include tariff measures for both intermediate

[2] Correa (2012) also find conflicting evidence using UK data, which suggested that the inverted-U relationship was the result of a positive relationship between 1973 and 1982 and a flat relationship between 1983 and 1994.

[3] One exception is Gorodnichenko et al. (2010) which studied the relationship between foreign competition and innovation in emerging economies, using data from the Business Environment and Enterprise Performance Survey. They find, among other things, that greater pressure from foreign competition stimulates innovation, where both measures are self-reported.

[4] Zietz and Fayissa (1992) and Funk (2003), for example, find that an increase in import competition leads to a rise in R&D expenditures in high-tech industries and export oriented US manufacturing firms; Teshima (2008) finds Mexican plants increase investment in R&D in the wake of tariff, but most of this R&D is focused on improving cost efficiency rather than creating new products. Bloom, Draca and Van Reenen (2009) find that Chinese imports accounted for approximately 14.7 percent of the increase in aggregate patenting per worker in their sample of European firms. Fernandes and Paunov (2010) find using a panel of Chilean manufacturing plants that increased import competition leads firms to engage in innovation in the form of product quality upgrading.

[5] Another strand of empirical papers, including Pavcnik (2002), study the impact of import competition on firm or industry productivity, typically measured on total factor productivity (TFP). Most find a positive and significant impact of import competition on productivity. At the industry level, productivity improvements may be due to reallocation effects such as those described in Melitz (2003) -- exposure to trade induces the most-productive firms in the industry to export and the least-productive firms in the industry to exit; as a result, aggregate industry productivity increases.

and final goods, as well as measures of import penetration and export share, which have also been studied with regard to their impact on innovation.

III. Empirical Methodology and Data

In order to test how trade variables impact innovation in the context of market competition, we start by replicating recent studies like Aghion et al. (2005) and Hashmi (2013) to confirm whether or not we can find evidence of this inverted U-shaped relationship between innovation and competition in our sample of US industries. We then explore how this relationship changes when we incorporate trade variables such as import and export share and tariffs in intermediate and final goods.

A. Data

The data used in our analysis is derived from several sources. We follow Aghion et al. (2005) and others in measuring innovative activity using patent data. Specifically, we use the NBER U.S. Patent Citations Datafile, as described in Browyn, Jaffe and Trajtenberg (2001), which includes such information as the date the patent was filed, the number of times the patent has been cited, and the U.S. patent class of all U.S. utility patents filed between 1976 and 2006. Because it takes an average of six years for a patent to be approved, and thus be included in the NBER datafile, we limit our analysis to patents filed between 1976 and 2000. Additional files in the NBER patent data project allow for this data to be matched to U.S. public corporations in the Compustat database, from which we will be able to calculate our measure of industry-level competition. This is the same basic sample used in Hashmi's (2013) analysis.

We measure the degree of innovation in an industry using the average number of patents applied for by the U.S. public corporations in that industry in a given year. As explained in Griliches (1998), there is a great deal of heterogeneity in the value of patents; in order to control for this heterogeneity we follow other researchers in weighting each patent by the number of times it has been cited by subsequent patents thus resulting in a citation weighted patent count. As shown in Bloom and Van Reenen (2002) most citations typically happen early on in a patent's life, but citations to a patent may still occur as long as 20 years after the initial patent application. As a result, patents applied for towards the end of the sample period will naturally have fewer citations than those applied for at the beginning of the sample period. We adjust for the potential truncation of citations to patents filed in later years using the methodology proposed in Bloom and Van Reenen (2002).[6]

[6] This method involves normalizing the citations made to each patent filed in year t with the predicted number of citations made to patents filed in the same year. This predicted number is calculated using the parameters from regressing citation counts made to the full sample of patents included in the NBER patent citation file on an eight-term Fourier expansion, thus resulting in a non-parametric citation truncation function.

We measure the degree of competition facing each firm using the Lerner Index, or the price cost margin. Specifically, for each firm in our sample, we calculate the price cost margin using variables in the Compustat database:

$$L_{it} = \frac{Operating\ Profit - Financial\ Cost\ of\ Capital}{Sales}.$$

In this equation, the cost of capital is assumed to be 0.085, and the capital stock held by each firm is calculated using the perpetual inventory method.[7] Much like our measure of innovative activity in the industry, our measure of competition in industry j is one minus the average Lerner Index of the individual public companies in the industry: $C_{jt} = 1 - \frac{1}{N_{jt}} \sum_{i \in j} L_{it}$. Note that this variable must be between 0 and 1; a value of 1 indicates a perfectly competitive industry, while values closer to zero indicates a less competitive market structure.[8]

The other variable we calculate from the Compustat data is an estimate of the technology gap in the industry, which we use to denote those firms in neck-and-neck industries (those in the bottom 50 percent our technology gap measure and unleveled industries (the top 50 percent). We calculate this technology gap by first calculating a first order approximation of each firm's total factor productivity (TFP).[9] The gap for each firm is defined as the percentage difference between the TFP of the most productive firm and the firm itself. The technology gap in the industry is the average across firms.

Our sample includes 7,064 public manufacturing firms included in the Compustat database. Note that we do not control for mergers and acquisitions, nor do we control for firm exit and entry over this time period; firms may be in our sample from anywhere between 2 and 25 years. There is a great deal of heterogeneity in the level of innovation amongst the firms in our sample, with the majority of firms filing zero patents but some extremely large outliers with citation weighted patent counts in the thousands; while the median citation weighted patent count amongst our firms is zero, the average count is 9.1 with a standard deviation of 59.1.

We average the citation weighted patent counts and Lerner indices from these public companies according to the three-digit SIC code that the firm itself lists as its primary industry in the Compustat database. Thus our final estimating sample includes an unbalanced panel of 117 industries between the years of 1976 and 2000.[10] Summary statistics from our sample are

---

[7] We calculate the real value of capital stock using industry-specific producer price indices, and assume a depreciation rate of eight percent in these calculations.

[8] We set the Lerner index for any firm with a negative price cost margin to zero, while those with Lerner indexes greater than 1 are assigned an index of 1.

[9] We approximate TFP using the equation $(y/L)/(k/L)^{\alpha}$, where y is the real value-added by the firm, L is the number of employees, and k is the capital stock. In these specifications, we use a value of one-third for the alpha parameter.

[10] We observe a small number of our industries for less than the entire sample period due to changes in industry definitions over the sample period.

included in Table 1, while Figure 6 illustrates the degree of heterogeneity in our measure of innovation across the industries in our sample.

B. Empirical Methodology

As in Hashmi (2013), we assume that our dependent variable, average citation weighted patent counts in the industry, is a count variable, in which the conditional mean number of patents filed by industry *i* in period *t*, y_{it}, is defined by the equation:

$$E(y_{it}|x_{it}) = e^{x_{it}\beta} \tag{1}$$

where *x* is a vector of explanatory variables, including the degree of competition in industry *i*. Statistical tests confirm that the model should be estimated using a negative binomial regression model to account for overdispersion in the measure of innovation (or unequal mean and variance).

Denoting the level of competition by the variable *c*, our baseline specification of the conditional mean is defined by the equation:

$$\ln(y_{it}) = \beta_0 + \beta_1 c_{it} + \beta_2 c_{it}^2 + \delta z_{it} + \varepsilon_{it} \tag{2}$$

In this equation, the vector *z* includes other variables that may impact the citation weighted patent count in an industry. For example, industries may have different propensities to patent depending on unobserved features of that industry; to control for this we include two-digit industry level fixed effects in all specification. We also include year-specific dummies to control for common macroeconomic or policy shocks. Should our sample exhibit the inverted-U relationship between competition and innovation, we would expect $\beta_1>0$ and $\beta_2<0$.

One notable problem with estimating Equation (2) is the potential endogeneity of the competition variable. Intuitively, if a successful innovation reduces the degree of competition in an industry, then the estimate of β_1 will be downwardly biased. To address this issue, we do two things. First, we instrument for competition by including a control function in Equation 2, where the control function includes the residual from a first stage regression of competition on a vector of instruments as well as the time and industry dummies discussed above, as explained in Wooldridge (2010). Following Hashmi (2013), we use a source-weighted average exchange rate for each industry for our instrument. Specifically, we construct industry-specific exchange rates using data on annual exchange rates associated with thirty-two of the leading US trade partners from the International Monetary Fund's International Financial Statistics database. The average across countries is calculated using industry-specific weights, as defined by each country's share of U.S. imports in the industry in 1972. Second, and following Im et al. (2015), we use lagged values of our competition and other right-hand side variables.

IV. Results

The results from our replication of the model estimated in Aghion et al. (2005) and Hashmi (2013) are included in Table 2. As described above, all specifications include year and industry fixed effects, in addition to a control function, and our estimated using a negative binomial regression. The excluded instrument (weighted exchange rate) in the first stage regression on competition is significant in all specifications, and the overdispersion variable is also significant, suggesting that the negative binomial is the proper empirical model.

Surprisingly, our results in Column 1 are quite different from those reported in Hashmi (2013), despite the fact that we use a nearly identical sample of US firms as he does. Specifically, like Aghion et al. (2005), we find positive evidence an inverted U-shape relationship between innovation and competition in our sample. This relationship is illustrated in Figure 7. Where our results differ from Aghion et al. (2005) is in how the industry's technology gap impacts this relationship. While Aghion et al. (2005) finds that the inverted-U is steeper in the neck-and-neck industries (as firms continuously try to escape competition), we find that the inverted -U is steeper for those in the unleveled industries.

The final two columns of Table 2 explore how trade variables impact the production of citation-weighted patents. As column 3 indicates, we find a positive relationship between tariffs on final goods and innovation. This suggests that US manufacturers are more likely to invest in R&D when they face less competition from imports. In contrast, industries which export a higher share of their output are more likely to engage in R&D. This latter result is highly consistent with Melitz (2003) and subsequent papers that show that firms engaged in global competition are more likely to be efficient.

In column 4, we include tariff variables. Our results indicate that US manufacturers are more likely to invest in R&D when they are insulated from foreign competition through tariffs on final goods. This would suggest that foreign competition in itself does not incentivize investment. In contrast, we find strong evidence that lower tariffs on intermediate goods increase R&D. This is consistent with Amiti and Konings (2007) and Goldberg et al. (2010), which find that lower tariffs on intermediate inputs increase productivity and product innovation. On the other hand, it does not support the theory that the technology imbedded in imported inputs serve as a substitute for R&D. However, it still may be the case that the technology imbedded and accessed through imported intermediate goods allows US manufacturers to shift their R&D towards other, perhaps more sophisticated technologies.

Columns 3 and 4 indicate that the general relationship between competition and innovation output does not change when we control for industry exposure to global markets, whether measured through tariffs or penetration rates. All of the specifications in Table 2 indicated statistical evidence of an inverted-U shape between the two variables. Although the marginal effect of competition on innovation output is statistically different when we control for trade variables,[11] in practice there is not a meaningful economic difference in the magnitudes of the estimates, as can be seen in Figure 8, which graphs the estimated predicted u-shape between competition and innovation when we omit versus control for exposure to international markets. This suggests that while there may be some omitted variable bias, the correlation between the exposure to international markets and competition does not pose as great an econometric problem as we may have feared.

In tables 3 and 4, divide our sample in half to check whether our results different during the early (1976-1987) or late (1988-1999) portion of our data. Interestingly, we find that during the early period, while the inverted U-shape relationship remains, there is no longer any difference between neck-and-neck industries compared to leader-laggard industries. Moreover, only the positive affect of higher final good tariffs on R&D remains, while the input-tariff variable is insignificant. This is opposite of what we see in the latter part of our sample (table 4), where the tariff on final goods is insignificant while the intermediate import tariff is negative and highly significant. It thus appears that lower tariffs on intermediate inputs only played a role in increasing innovation starting in the late 1980s.

V. Conclusion

Our empirical analysis seeks to determine whether the inverted U-shaped relationship between competition and innovation found in previous studies remains after controlling for trade variables such tariffs and import penetration. Our results confirm this inverted U-shape relationship, indicating that firms in industries with low levels of competition are more likely to innovate in the wake of increased competition as they attempt to escape competition, while those in highly competitive industries will decrease innovation in the wake of increased competition as the profit incentive to innovate dissipates. We also find some interesting regarding trade and innovation. First, tariffs on final goods are positively associated with innovation, as measured by citation-weighted patens of US manufacturers, although this result only holds for the first part of our sample (1976-1987). Second, and consistent with previous studies, lower tariffs on intermediate goods appear to stimulate innovation, although this result is only found in the latter half of our sample (1988-1999).

We also find evidence that increasing export share is associated with innovation, a results consistent with numerous previous theoretical and empirical studies. However, our results indicate that increasing import penetration reduces innovation. Since our model controls for overall market competition (as measured by price-cost margin), which incorporates the effect of both domestic and foreign competition, it may be the case that the isolated impact of import competition, is to undermine innovation.

[11] The p-value of the chi-squared test comparing the coefficients between column 2 and column 3 for example is 0.036, thus we reject the null hypothesis that the estimated magnitude of the coefficients is the same across the two specifications.

References

Aghion, Philippe, Nick Bloom, Richard Blundell, Rachel Griffith, and Peter Howitt (2005), "Competition and Innovation: An Inverted-U Relationship." *Quarterly Journal of Economics* 120(2): 701-728.

Amiti, Mary, and Jozef Konings (2007). "Trade liberalization, intermediate inputs, and productivity: Evidence from Indonesia." *The American Economic Review*: 1611-1638.

Bloom, Nicholas and John Van Reenen (2002), "Patents, Real Options and Firm Performance," *The Economic Journal*, 112: 97–116.

Bloom, Nicholas, Mirko Draca, and John Van Reenen (2009), "Trade Induced Technical Change? The Impact of Chinese Imports on Innovation, IT and Productivity," NBER Working Paper No. 14975.

Bustos, Paula (2011), "Trade Liberalization, Exports, and Technology Upgrading: Evidence on the Impact of Mercosur on Mexican Firms," *American Economic Review* 101: 304-340.

Coe, David T., and Elhanan Helpman (1995). "International R&D spillovers." *European economic review* 39.5: 859-887.

Correa, Juan A. (2012), "Competition and Innovation: An Unstable Relationship," *Journal of Applied Econometrics* 27(1): 160-166.

Correa, Juan A. and Carmine Ornaghi (2014). "Competition and Innovation: Evidence from U.S. Patent and Productivity Data," *Journal of Industrial Economics* 62(2): 258-285.

Ederington, J. and P. MacCalman (2008), "Endogenous Firm Heterogeneity and the Dynamics of Trade Liberalization," *Journal of International Economics* 71(1): 52-71.

Feenstra, R., J. Romalis, and P. Schott (2001). "U.S. Imports, Exports, and Tariff Data, 1989-2001." NBER Working Paper No. 9387.

Fernandes, Ana Margarida and Caroline Paunov (2010), "Does Trade Stimulate Innovation? Evidence from Firm-Product Data," OECD Working Paper No. 286.

Funk, Mark (2003). "The Effects of Trade on Research and Development." *Open Economies Review* 14(1): 29-41.

Goldberg, Pinelopi Koujianou, Amit Kumar Khandelwal, Nina Pavcnik, and Petia Topalova (2010). "Imported Intermediate Inputs and Domestic Product Growth: Evidence from India." *The Quarterly journal of economics* 125.4: 1727-1767.

Gorodnichenko, Yuriy, Jan Svejnar, and Katherine Terrell (2010), "Globalization and Innovation in Emergin Markets," *American Economic Review: Macroeconomics* 2(2): 194-226.

Griliches, Zvi (1998), "Patent Statistics as Economic Indicators: A Survey," in Z. Griliches (ed.) *R&D and Productivity: The Econometric Evidence"* Chicago: University of Chicago Press.

Grossman, G. and E. Helpman (1991a) Innovation and Growth in the Global Economy. Cambridge, MA: MIT Press.

Grossman, G. and E. Helpman (1991b), "Quality Ladders in the Theory of Growth," *Review of Economic Studies* 58: 43-61.

Hall, Browyn, Adam Jaffe, and Manuel Trajtenberg (2001), "The NBER Patent Citation Data File: Lessons, Insights and Methodological Tools," *NBER Working Paper No. 8498.*

Hashmi, Aamir Rafique (2013). "Competition and Innovation: The Inverted-U Relationship Revisited," *Review of Economics and Statistics* 95(5): 1653-1668.

Im, Hyun Joong, Park, Young Joon, and Shon, Janghoon (2015). "Product market competition and the value of innovation: Evidence from US patent data." *Economics Letters* (137) 78–82.

Liu, Quing, and Qiu, Larry D. (2016). "Intermediate input imports and innovations: Evidence from Chinese firms' patent filings." *Journal of International Economics* (103) 166–183.

Melitz, Marc (2003), "The Impact of Trade on Intra-Industry Reallocations and Aggregate Productivity Growth," *Econometrica*, 71: 1695-1725.

Nickell, Stephen J. (1996), "Competition and Corporate Performance," *Journal of Political Economy* 104(4): 724-746.

Pavcnik, Nina (2002), "Trade Liberalization, Exit and Productivity Improvements: Evidence from Chilean Establishments," *Review of Economic Studies* 69(1): 1263-1297.

Rodrik, Dani (1992), "Closing the Productivity Gap: Does Trade Liberalization Really Help," in G. Helleiner (ed.) *Trade Policy, Industrialization and Development* Clarendon Press, Oxford.

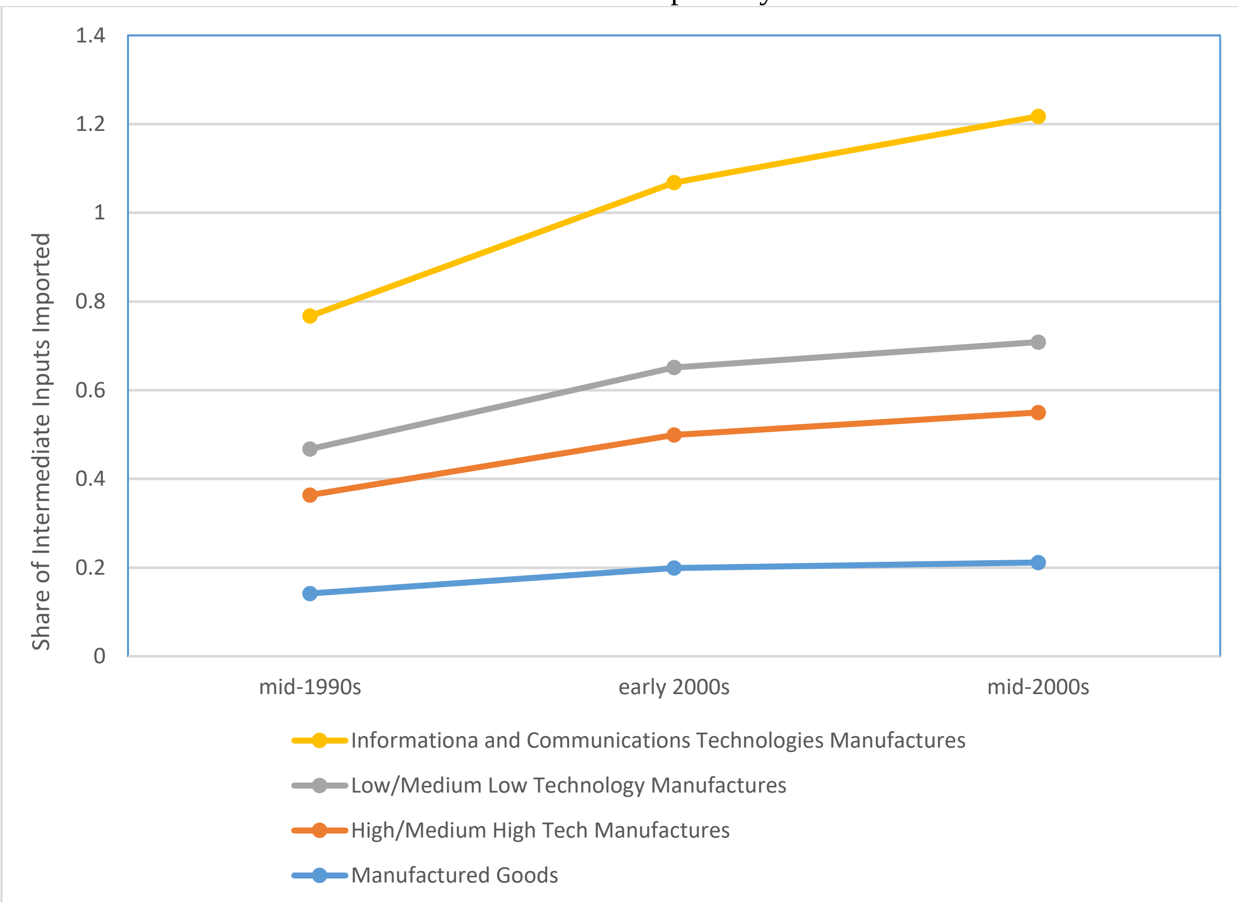
Schumpeter, Joseph A. (1942), *Capitalism, Socialism, and Democracy*, Harper, New York.

Teshima, Kensuke (2008), "Import Competition and Innovation at the Plant Level: Evidence from Mexico," Working Paper.

Wooldridge, Jeffrey M. (2010). *Econometric analysis of cross section and panel data*. MIT press.

Zietz, Joachim and Bichaka Fayissa (1992). "R&D Expenditures and Import Competition: Some Evidence for the United States," *Review of World Economics* (*Weltirtschaftliches Archiv)*128(1): 155-164.

Figure 1
Intermediate Good Imports by Sector



Source: OECD.

Figure 2
Intermediate Good Imports by Sector

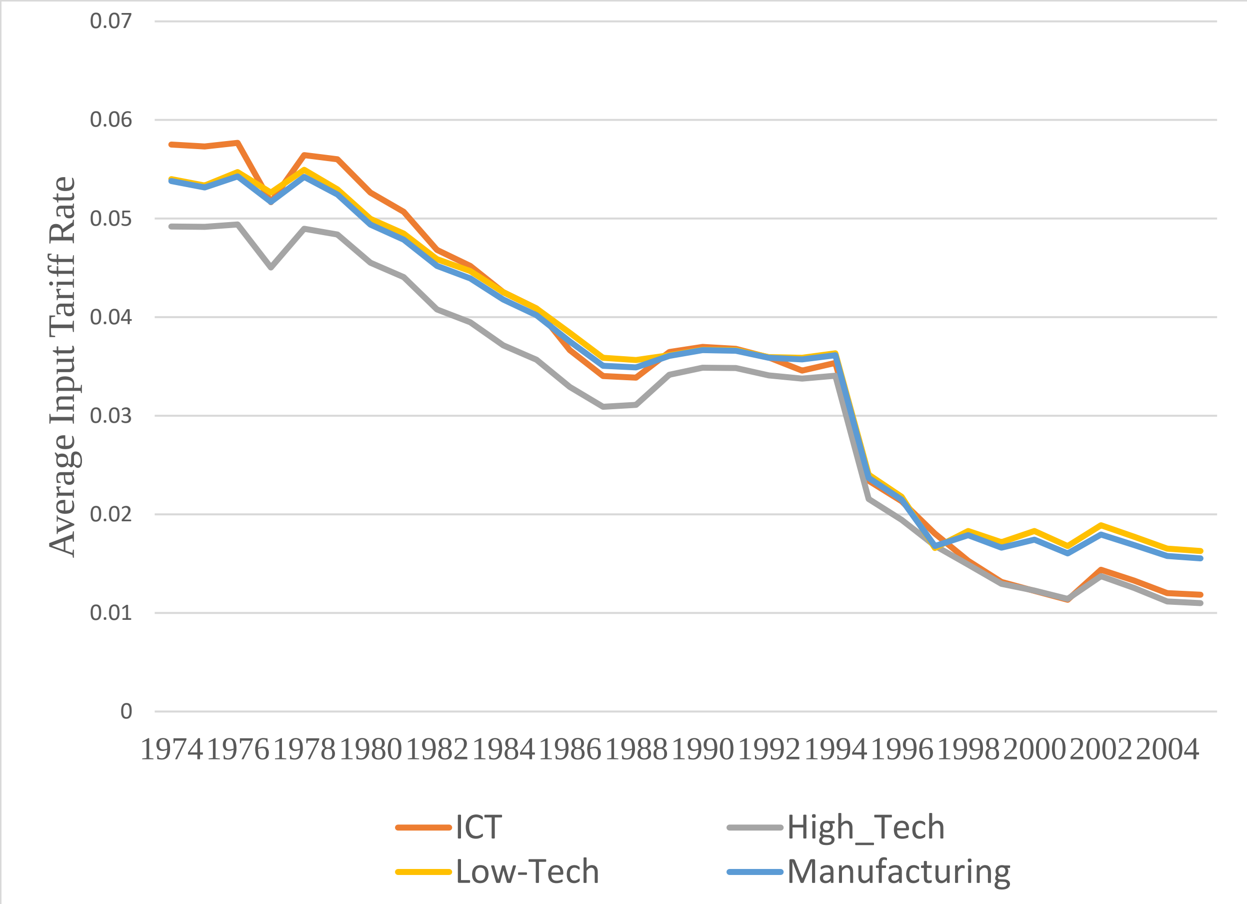
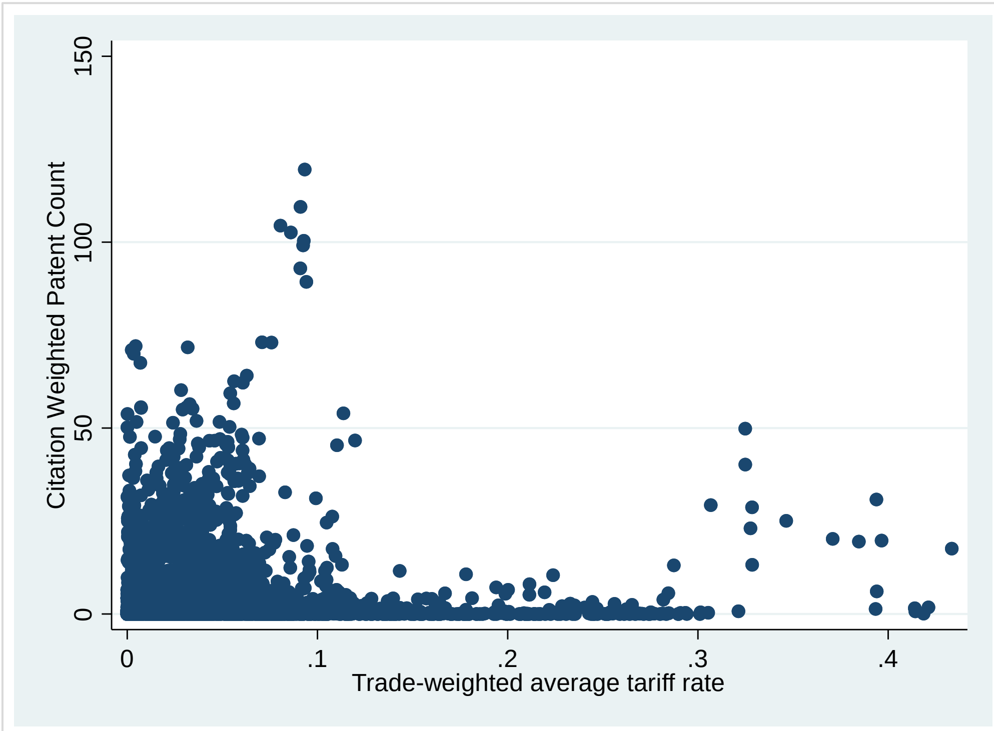


Figure 3: Innovation and tariffs, 1975-1999

3a: Innovation and final good tariffs, 1975-1999



3b: Innovation and input tariffs, 1975-1999

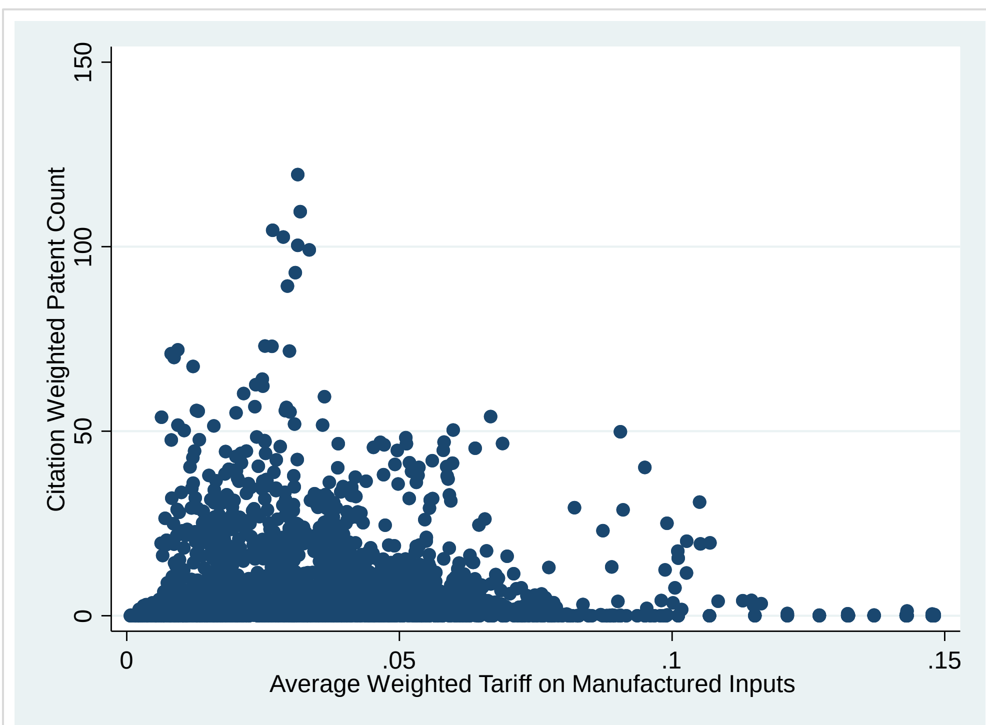
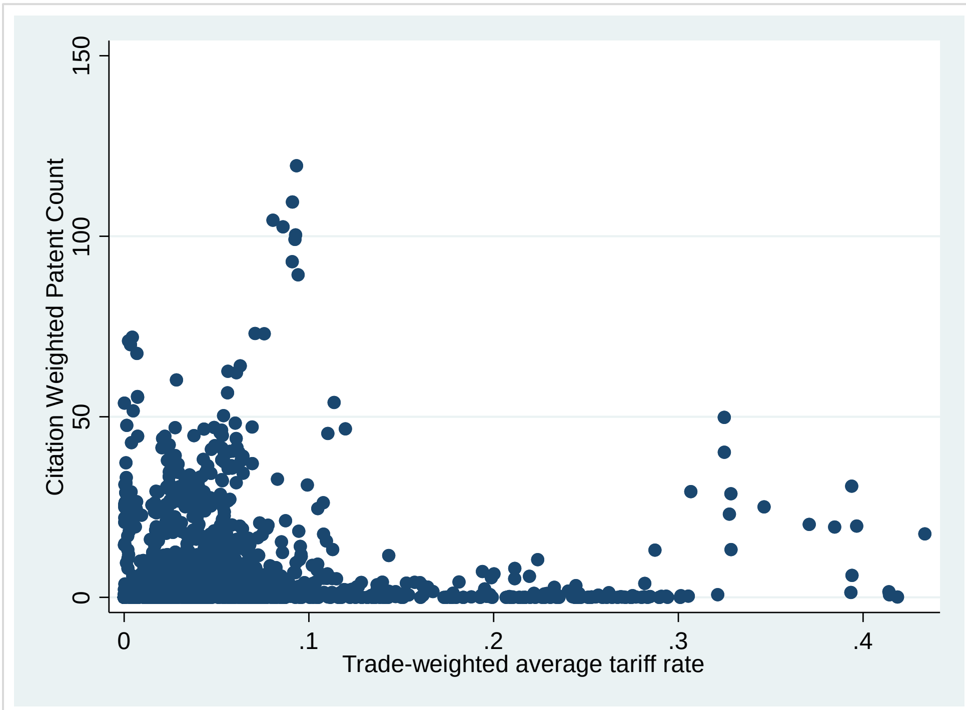


Figure 4: Innovation and tariffs, 1975-1987

4a: Innovation and final good tariffs, 1975-1987



4b: Innovation and input goods, 1975-1987

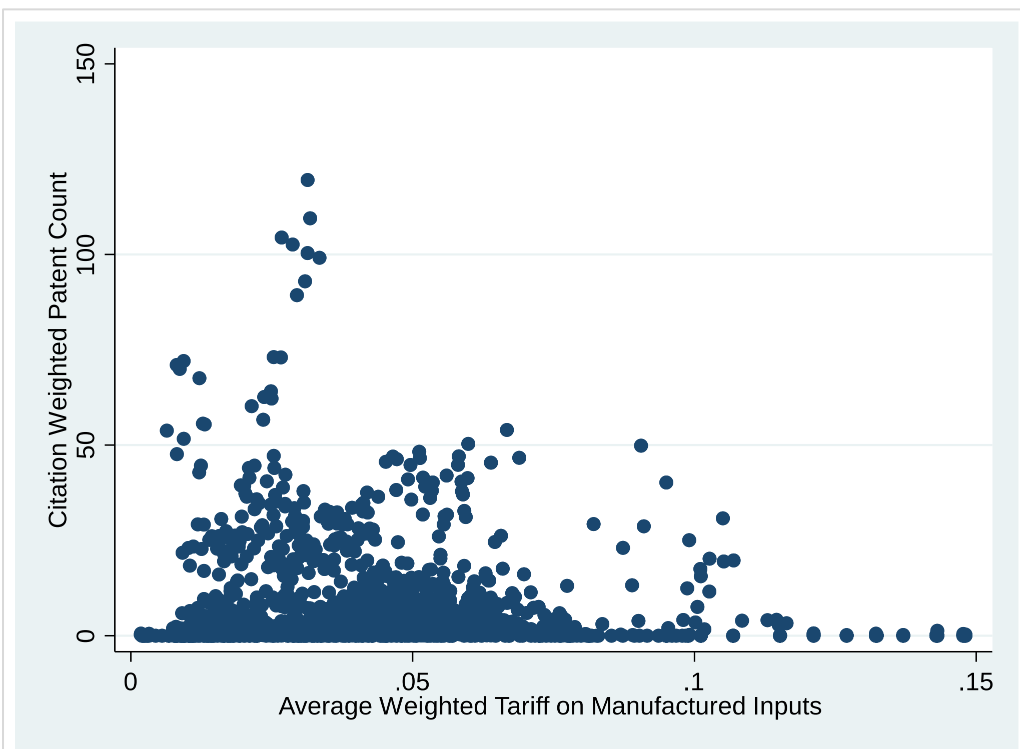
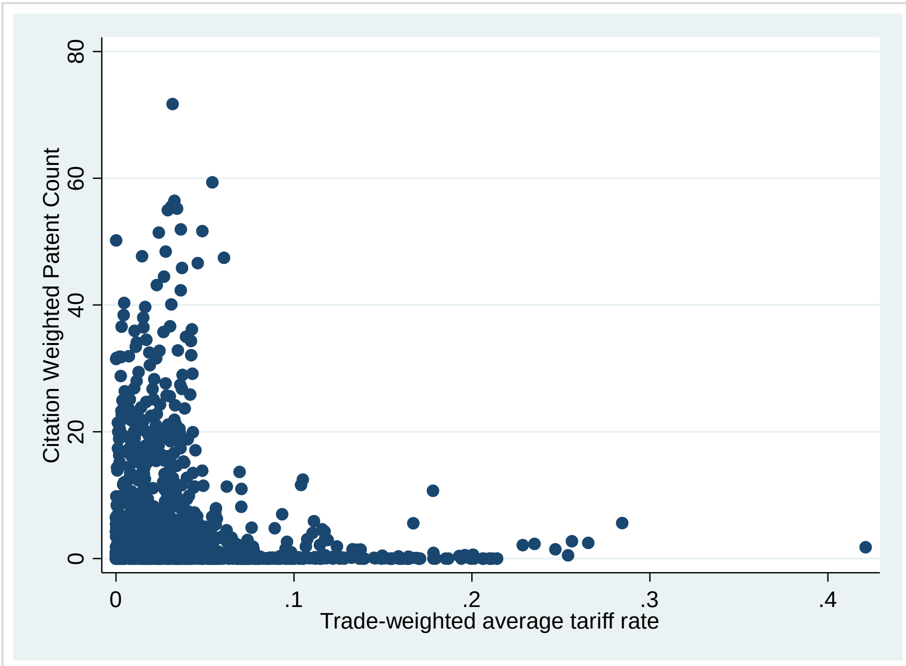


Figure 5 - Innovation and final good tariffs, 1988-1999

5a: Innovation and final good tariffs, 1988-1999



5b: Innovation and input tariffs, 1988-1999

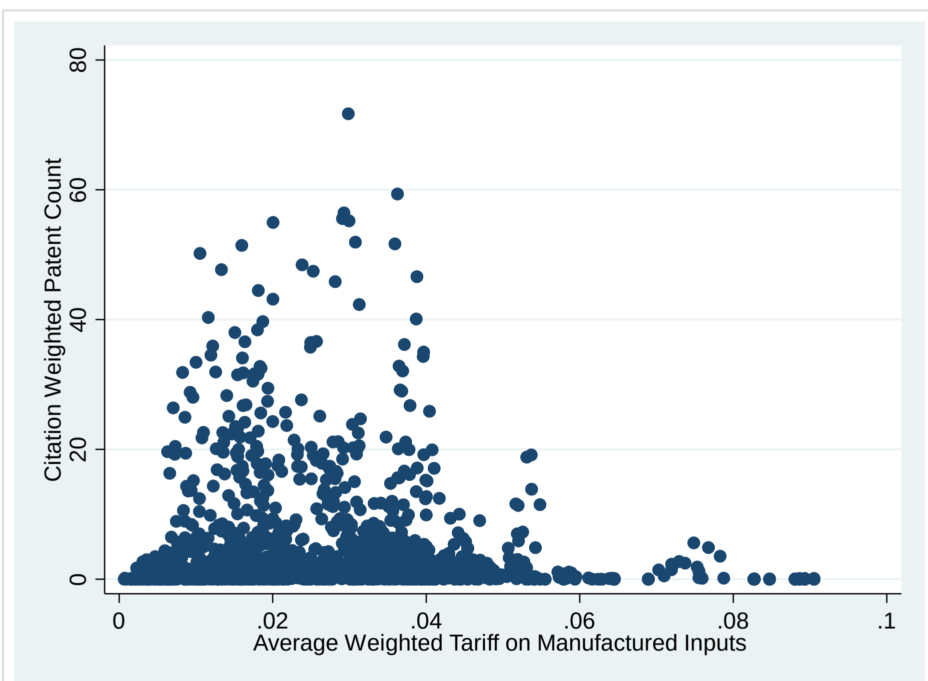


Figure 6
Distribution of Citation Counts Across US Manufacturing Industries, 1976-2000

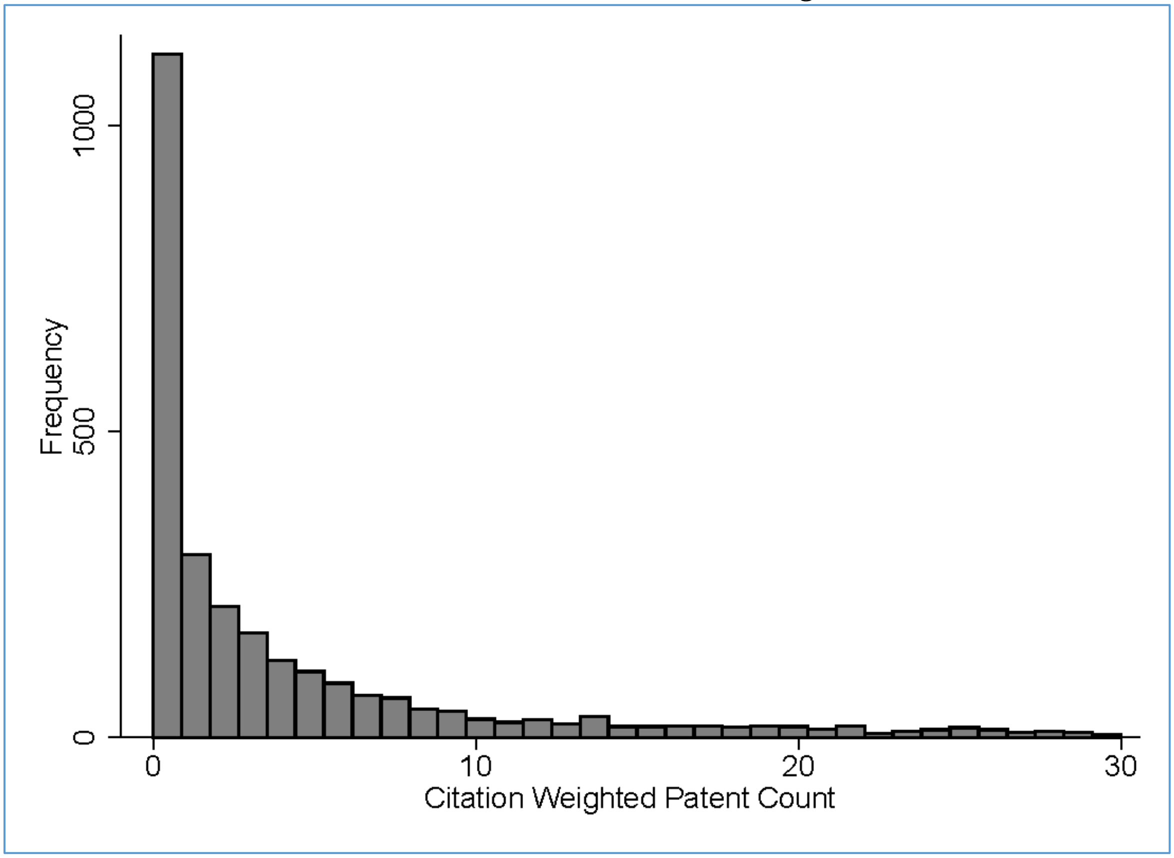


Figure 7
Competition versus Innovation

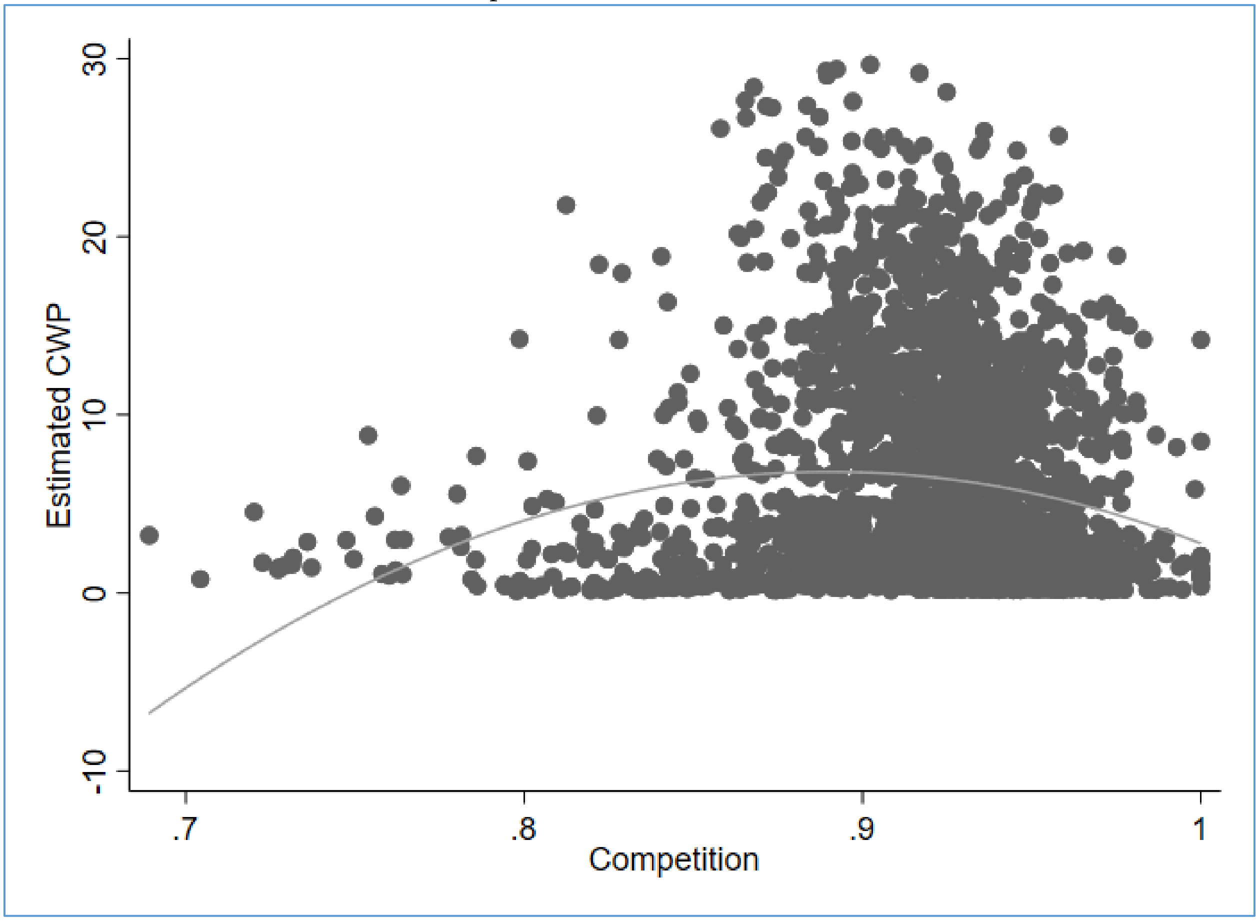


Figure 8
Estimated Relationship between Competition and Innovation

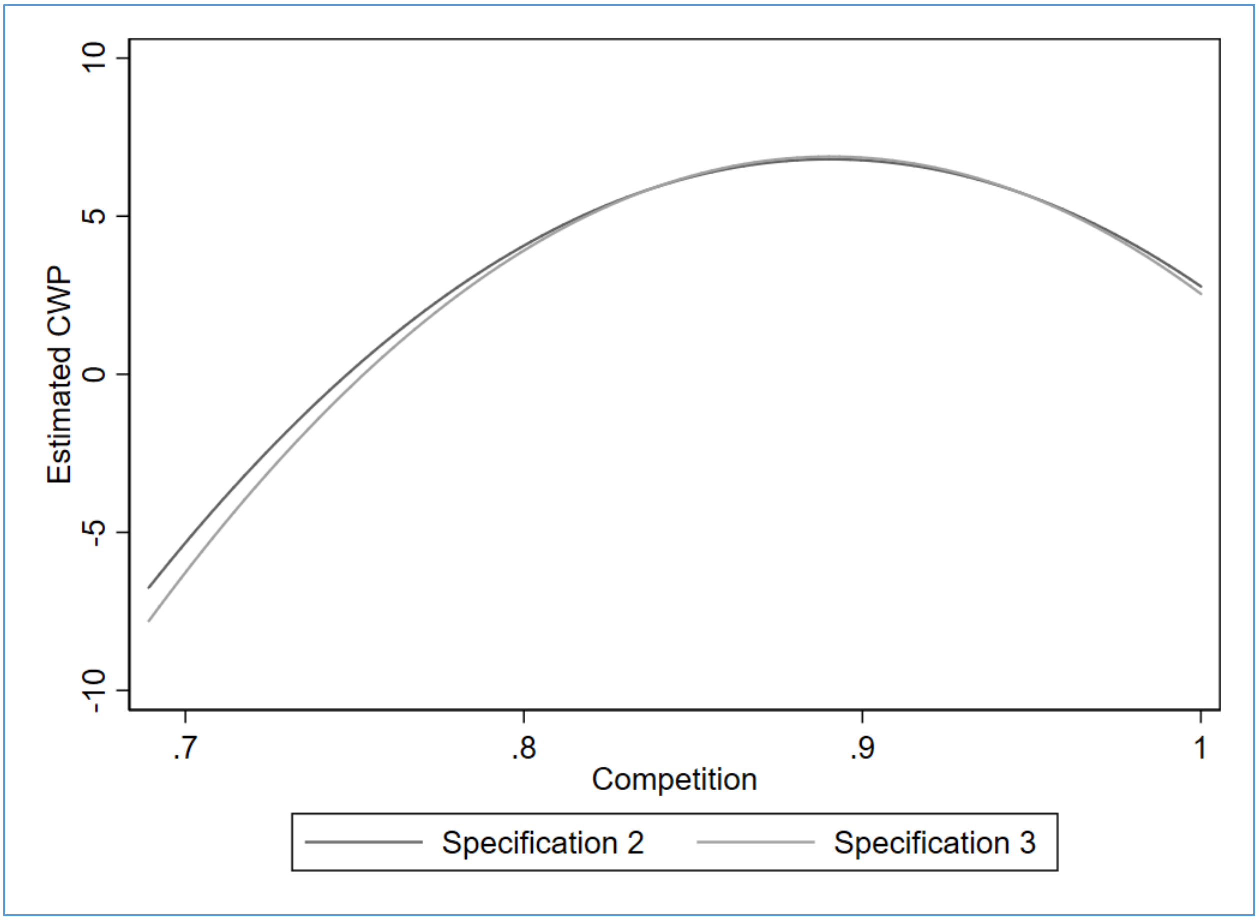


Table 1
Summary Statistics

Variable	p(10)	Median	p(90)	Mean	Std. Deviation
Competition	0.876	0.924	0.957	0.918	0.037
Innovation	0.000	1.717	19.150	6.187	11.404
TFP Gap	0.241	0.582	0.835	0.556	0.230
No. of Industries	126				
Time Period	1976-2000				

Table 2

Empirical Results: The Impact of Competition on Innovation (1976-1999)

	(1) Patents	(2) Patents	(3) Patents	(4) Patents
$\text{Competition}_{j,t-1}$	102.6^{***}	88.99^{***}	81.13^{***}	83.93^{***}
	(29.74)	(31.23)	(29.69)	(31.37)
$\text{Competition squared}_{j,t-1}$	-56.22^{***}	-50.35^{***}	-45.98^{***}	-47.74^{***}
	(16.50)	(17.07)	(16.26)	(17.14)
$\text{Competition}_{j,t-1}$ *x* neck-&-neck dummy		-5.021^{**}	-4.936^{**}	-4.755^{**}
		(2.138)	(2.124)	(2.136)
$\text{Competition squared}_{j,t-1}$ *x* neck-&-neck dummy		5.273^{**}	5.158^{**}	4.956^{**}
		(2.326)	(2.310)	(2.323)
$\text{Import penetration}_{j,t-1}$			-0.987^{***}	
			(0.270)	
$\text{Export share}_{j,t-1}$			0.738^{**}	
			(0.356)	
$\text{Tariff}_{j,t-1}$				3.330^{***}
				(1.179)
$\text{Input tariff}_{j,t-1}$				-7.627^{**}
				(3.186)
Control function in regression	-0.852	-0.957	-0.896	-0.541
	(1.605)	(1.590)	(1.581)	(1.589)
Significance of overdispersion parameter	0.186^{***}	0.177^{***}	0.174^{***}	0.170^{***}
	(0.0341)	(0.0342)	(0.0340)	(0.0341)
N	2875	2875	2872	2795
Two-digit SIC industry fixed effects	yes	yes	yes	yes
Year fixed effects	yes	yes	yes	yes

Robust standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

F-statistic (p-value) of excluded instruments in reduced form = 14.20 (0.000)

Table 3
Empirical Results: The Impact of Competition on Innovation (1976-1987)

	(1) Patents	(2) Patents	(3) Patents	(4) Patents
$\text{Competition}_{j,t-1}$	140.0***	123.9***	110.5**	120.3***
	(43.02)	(45.26)	(43.26)	(43.27)
$\text{Competition squared}_{j,t-1}$	-77.39***	-69.91***	-62.28***	-67.96***
	(23.87)	(24.71)	(23.66)	(23.65)
$\text{Competition}_{j,t-1}$ *x* neck-&-neck dummy		-3.867	-3.277	-3.647
		(2.627)	(2.622)	(2.528)
$\text{Competition squared}_{j,t-1}$ *x* neck-&-neck dummy		4.095	3.448	3.782
		(2.860)	(2.859)	(2.752)
$\text{Import penetration}_{j,t-1}$			-0.790	
			(0.511)	
$\text{Export share}_{j,t-1}$			-1.070	
			(0.724)	
$\text{Tariff}_{j,t-1}$				2.975**
				(1.397)
$\text{Input tariff}_{j,t-1}$				-4.668
				(4.270)
Control function in regression	-1.723	-1.624	-1.609	-1.885
	(1.972)	(1.963)	(1.924)	(1.906)
Significance of overdispersion parameter	0.138***	0.134***	0.131***	0.124***
	(0.0475)	(0.0473)	(0.0465)	(0.0474)
N	1441	1441	1441	1405
Two-digit SIC industry fixed effects	yes	yes	yes	yes
Year fixed effects	yes	yes	yes	yes

Robust standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$
F-statistic (p-value) of excluded instruments in reduced form = 2.79 (0.095)

Table 3

Empirical Results: The Impact of Competition on Innovation (1988-1999)

	(1) Patents	(2) Patents	(3) Patents	(4) Patents
$\text{Competition}_{j,t-1}$	146.3***	135.4***	121.3***	120.4***
	(36.78)	(37.60)	(36.52)	(38.02)
$\text{Competition squared}_{j,t-1}$	-80.56***	-76.01***	-68.25***	-68.27***
	(20.36)	(20.66)	(20.11)	(20.87)
$\text{Competition}_{j,t-1}$ *x* neck-&-neck dummy		-5.815*	-6.705**	-6.519**
		(3.128)	(3.015)	(3.225)
$\text{Competition squared}_{j,t-1}$ *x* neck-&-neck dummy		6.030*	6.918**	6.784*
		(3.388)	(3.264)	(3.492)
$\text{Import penetration}_{j,t-1}$			-1.828***	
			(0.339)	
$\text{Export share}_{j,t-1}$			2.062***	
			(0.447)	
$\text{Tariff}_{j,t-1}$				-0.557
				(1.727)
$\text{Input tariff}_{j,t-1}$				-14.31**
				(5.559)
Control function in regression	2.012	1.388	0.811	2.599
	(2.643)	(2.656)	(2.533)	(2.767)
Significance of overdispersion parameter	0.123***	0.106**	0.0887*	0.105**
	(0.0455)	(0.0463)	(0.0454)	(0.0480)
N	1434	1434	1431	1390
Two-digit SIC industry fixed effects	yes	yes	yes	yes
Year fixed effects	yes	yes	yes	yes

Robust standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

F-statistic (p-value) of excluded instruments in reduced form = 13.51 (0.000)