Product Market Competition and Option Prices*

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Abstract

Most firms face some form of competition in product markets. The degree of competition a firm faces feeds back into its cash flows and affects the values of the securities it issues. Through its effects on stock prices, product market competition affects the prices of options on equity and naturally leads to an inverse relationship between equity returns and volatility, generating a negative volatility skew in option prices. Using a large sample of U.S. equity options, we provide empirical support for this finding and demonstrate the importance of accounting for product market competition when explaining the cross-sectional variation in option skew.

Keywords: Product market competition; Investment; Leverage effect; Option skew.

JEL Classification Numbers: G13; G31; G32.

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On September 29, 2016, *The Guardian* reported that "oil and share prices rose after OPEC members struck a deal to limit crude output for the first time since 2008, in an attempt to ease the global glut that [had] more than halved crude prices." On the same day, Citigroup analysts indicated that "sustained higher oil prices, all else equal, could see U.S. [shale] production increase again, and hence limit the oil price move [...], absent a demand driven move."As this event starkly illustrates, firms interact in product markets to generate cash flows. These cash flows are in turn priced in financial markets, determining stock prices and returns. This paper shows that, through its effects on stock prices, product market competition naturally leads to an inverse relationship between equity returns and subsequent volatility changes, thereby generating a negative volatility skew in option prices. The paper also provides evidence that competition and option skew are, as predicted, cross-sectionally negatively related. By doing so, it illustrates the value of going beyond stock return data and using relevant information from firm-level option prices to better understand the relation between competition and equity risk and value. To the best of our knowledge ours is the first paper that bridges the gap between corporate finance theory and the option pricing literature by endogenizing the equity volatility process and linking its dynamics to the intensity of competition in product markets.

The standard starting point for option pricing models is to specify an exogenous process for underlying stock prices. In the Black and Scholes (1973) model, stock prices are lognormally distributed and the volatility of stock returns is constant, but this specification has been empirically rejected. Notably, a robust pattern in the data is that stock return volatility increases after stock prices fall, a phenomenon coined as the leverage effect in the option pricing literature.[1] In this paper, we show that product market competition provides a natural economic mechanism for this enduring empirical regularity and can thus potentially explain the negative option skew. We do so by constructing a dynamic model in which firms compete in product markets and by showing how product market competition affects the (endogenous) volatility of stock returns as well as the option skew.

To demonstrate the effects of product market competition on stock return volatility and the option skew, we construct a real options model in which firms compete to offer a homogenous

[1]This empirical regularity implies that risk-neutral densities implicit in observed option prices tend to be negatively skewed. This feature has been first attributed to financial leverage by Black (1976). The evidence on this financial leverage channel is mixed however. See the discussion of the related literature below.

product in a market where demand is stochastic. In this model, each firm's output is constrained by its production capacity but firms have the option to invest at a cost in additional capacity as demand for their product increases. As in prior such models, competition affects equity risk through two distinct channels. First, since firms in more competitive industries have lower profit margins to buffer adverse demand shocks, these firms have higher operating leverage. This *operating leverage channel* predicts a positive relation between competition and equity risk. Second, new investments by the firm and its competitors buffer the effects of positive demand shocks on equity risk via the addition of new capacity (i.e. endogenous supply shocks). More competition implies larger and more frequent supply shocks, further smoothing output and stock prices. This *supply channel* thus predicts a negative relation between competition and risk. Overall, product market competition may thus increase or decrease equity risk and stock returns, depending on which of these two channels dominates, a result first established by Aguerrevere (2009).

A second and separate prediction of the model is that, in the presence of competition in product markets, stock return volatility is negatively related to stock prices, producing a negative volatility skew in the prices of options on equity. This prediction is again driven by the supply and operating leverage channels identified above. Notably, as output and stock prices rise, additional investment by competitors becomes more likely. The anticipated increase in supply attenuates the effects of demand volatility on the output price and equity value, implying that stock return volatility decreases after equity value increases. As we show in the paper this mechanism becomes stronger as the frequency and the size of (endogenous) capacity changes increase, that is as the number of firms in the industry increases. Additionally, as output and stock prices rise, operating leverage decreases, leading to a drop in equity risk that is stronger in more competitive environments. Product market competition thus yields a negative relation between volatility and equity returns that becomes more negative as competition intensifies. In short, competition naturally generates a negative volatility skew in option prices. In addition, the model predicts that this volatility skew should be negatively related to the intensity of product market competition.

We proceed by empirically testing our main hypothesis for a negative relation between option skew and the intensity of product market competition. In this analysis, we use a large sample of individual U.S. equity options from 1996 to 2014 and two measures of option skew. Our main measure is the model-free implied skewness—the most commonly used skewness measure in the option pricing literature—which represents a non-parametric estimate of the skewness of the risk-neutral (stock price) density implied by individual stock option prices. In robustness tests, we also use the difference between Black-Scholes implied volatilities of out-of-the-money calls and out-of-the-money puts, scaled by the average of implied volatilities of at-the-money puts and calls. We then test whether option skew is related to product market competition, as measured by the product market fluidity measure of Hoberg, Phillips, and Prabhala (2014), the text based Herfindahl-Hirschman Index (HHI TNIC) of Hoberg and Phillips (2016), or the number of firms in SIC and NAIC industries.

Consistent with our main hypothesis, we find that the effect of product market fluidity, our main proxy for competition, on option skew is negative and highly significant in all specifications. The effect of competition is also economically large: Keeping everything else constant, a firm in a perfectly competitive industry has an option skew approximately 15 basis points below that in a monopoly industry, which corresponds to about 42% of its mean value in our sample. Our analysis also demonstrates the robustness of our main result to the use of alternative competition or skewness measures. We also examine whether barriers to entry, which should limit competition, affect the option skew. Consistent with our hypothesis, coefficients on the interaction terms of barriers to entry and fluidity are positive and highly statistically significant in all regressions specifications. Lastly, because competitive entry threats are likely to be weaker in recessions than in expansions, we also examine whether the effect of competition on option skew is present in both expansions and recessions. We find that, as expected, product market fluidity has no effect on the option skew in recessions.

To strengthen the interpretation of the results, we implement a differences-in-differences analysis around an exogenous shock to the competitiveness of the US manufacturing industries. The goal of this analysis is to validate our empirical results in a setting that, by design, reduces endogeneity concerns. To do so, we explore the effects of the U.S. granting of Permanent Normal Trade Relations (PNTR) to China, which was passed by Congress in October 2000 and became effective upon China's accession to the WTO at the end of 2001. This PNTR status ended the uncertainty associated with annual renewals of China's NTR status and reduced the expected import tariffs applied to China, thereby increasing competition for US manufacturing industries. Consistent with our main hypothesis of a negative relation between competition and option skew, we find that the option skew for firms in manufacturing industries decreased by about 5 to 11 basis points (representing 14% to 30% of its mean value) relative to firms in non-manufacturing industries following the granting of the PNTR status to China.

This paper is part of a larger literature that links industrial organization to issues in financial economics (see for example Leahy (1993), Lambrecht (2001), Grenadier (2002) Garlappi (2004), or Miao (2005)). Most relevant to our work is the theoretical contribution of Aguerrevere (2009), which shows that the interaction between product market structure and investment decisions has implications for returns and demonstrates that, depending on operating leverage, product market competition may increase or decrease expected stock returns. In related work, Carlson, Dockner, Fisher, and Giammarino (2014) show in a leader-follower equilibrium that own-firm and competitor risks and required returns move together through contractions and oppositely during contractions, so that industry concentration is positively (respectively negatively) related to industry risk and expected returns during expansions (respectively recessions). Kogan (2004) develops a model in which real investment is irreversible and subject to adjustment costs and shows that for firms with high-q (respectively low-q) volatility and equity returns should be positively (respectively negatively) related. While the theoretical motivation of our paper is closely related to these studies, to the best of our knowledge ours is the first paper that links product market competition to option skew and demonstrates that competition yields a negative relation between volatility and equity returns that becomes more negative as competition intensifies.

A number of empirical studies examine the relation between product market competition and stock returns.[2] Early research by Hou and Robinson (2006) finds that equity returns are lower in more concentrated industries, where concentration is measured using Compustat-based measures. More recent research by Gu (2016) also finds that firms in competitive industries earn higher expected returns than firms in concentrated industries, especially among

[2]A number of related studies also show that a wide range of asset pricing phenomena have important industry components. See for example Moskowitz and Grinblatt (1999), Cohen, Polk, and Vuolteenaho (2003), Hou (2007), or Giroud and Mueller (2011).

R&D-intensive firms. By contrast, Bustamante and Donangelo (2017) documents a negative relation between product market competition and equity returns using alternative measures of industry concentration. This conflicting evidence is consistent with the complex relation between competition and returns first noted in Aguerrevere (2009), which implies that empirical tests based on the level of stock returns may not be very informative about the nature of the competitive environment facing firms and vice versa.[3] As discussed above, while the relation between competition and returns can be positive or negative, theory unambiguously predicts that competition should lead to a negative relation between equity returns and volatility, thereby generating a negative volatility skew in option prices. Our empirical analysis tests this prediction and finds very strong support for it in the data. Our analysis thus shows that option price data potentially represents a valuable source of information when trying to understand the relation between competition and equity risk and value.

Our paper also relates to the large literature on the leverage effect, according to which the inverse relationship between stock prices and stock-return volatility is due to financial leverage (Black (1976)). Toft and Prucyk (1997) and Geske, Subrahmanyam, and Zhou (2016) derive option pricing models on levered equity and provide evidence consistent with this hypothesis. The validity of this leverage explanation has however been partly called into question by Figlewski and Wang (2000), who document that there is no effect on volatility when leverage changes because of a change in debt or in the number of shares. Similarly, Hasanhodzic and Lo (2011) construct from Compustat a sample of 667 firms that they define as all-equity financed and find that the volatility of these all-equity firms exhibits the same negative relation between returns and volatility that is characteristic of the leverage effect. Our paper provides an alternative economic mechanism for this negative relation.

The paper is organized as follows. Section 1 presents the model and derives our main results on the effects of competition on option prices and option skew. Section 2 describes the data. Section 3 presents our empirical results and demonstrates the importance of accounting for competition when explaining cross-sectional variation in option skew. Section 4 implements

[3]In related research, Hoberg and Philips (2010) find that during industry booms systematic risk decreases more for firms in competitive industries than for firms in concentrated industries and during industry busts systematic risk decreases more for firms in concentrated industries than for firms in competitive industries. Valta (2012) shows that the cost of bank debt also depends on a firm's competitive environment.

a difference-in-differences analysis around an exogenous shock to the competitiveness of the US manufacturing industries. Section 5 concludes.

1. Model

This section presents a model based on Grenadier (2002) and Aguerrevere (2009) that illustrates the effects of product market competition on stock return volatility and the option skew. In this model, the intensity of product market competition is captured by the number of firms in a given industry. Competition affects output dynamics, output prices and, as a result, the dynamics of stock return volatility and the option skew.

Consider an oligopolistic industry with n identical firms producing a single, homogeneous good in a market where demand is stochastic. At time t, firm i produces $Q_{i,t}$ units of output at marginal cost $c \geq 0$. The output price P_t is a function of total industry output $Q_t = \sum_{i=1}^{n} Q_{i,t}$ and a stochastic demand shock Y_t such that:

$$P_t = Y_t Q_t^{-\frac{1}{\gamma}} \tag{1}$$

where the constant $\gamma > 1$ is the elasticity of demand. The industry shock $Y = (Y_t)_{t \geq 0}$, which reflects the relative strength of the demand side of the market, is governed under the risk neutral probability measure $\mathbb{Q}$ by the geometric Brownian motion

$$dY_t = (r - \delta) Y_t dt + \sigma Y_t dW_t,$$

where $r > 0$ is the risk-free rate of return, δ and σ are positive constants, and $W = (W_t)_{t \geq 0}$ is a standard Brownian motion.

At any time t, firms play a static Cournot game in which each firm chooses its output $Q_{i,t}$ to maximize profits and conditions its choice on the choices of other firms.[4] At each time t, each firm can increase its output by an increment $dQ_{i,t}$. The capital input is homogenous and

[4] Grenadier (2002) and Aguerrevere (2009) focus on open-loop equilibria in investment strategies. Back and Paulsen (2009) discuss the implications of this assumption.

perfectly divisible and the firm is a price-taker in the market for capital goods. The price of a new unit of capacity is constant, denoted by $I > 0$, and investment is irreversible, implying that the process $Q_{i,t}$ is non-decreasing. For each firm i, let $Q_{-i} = \{Q_1, ..., Q_{i-1}, Q_{i+1}, ..., Q_n\}$ denote the output choices of firm i's competitors. A $n-$tuple of strategies $\{Q_1^*, ..., Q_n^*\}$ is a Nash industry equilibrium if $Q_i^* = Q_i(Y, Q_{-i}^*)$ for all i.

Because the industry is composed of n identical firms, we have $Q_{i,t} = \frac{Q_t}{n}$ and $Q_{-i,t} = \frac{(n-1)Q_t}{n}$. This assumption also implies that firms only need to condition their output choices on the level of the demand shock and total output. The optimal investment strategy for firm i is then the solution to:[5]

$$V_n(Y,Q) = max_{\{Q_{i,t}:t>0\}} \mathbb{E}\left[\int_0^{+\infty} e^{-rt} \left(Q_{i,t}(Y_t Q_t^{-\frac{1}{\gamma}} - c)dt - I dQ_{i,t} \right) \middle| Y_0 = Y, Q_0 = Q \right],$$

where the right hand side is the present value of the cash flows from operating the firm's assets, net of the cost of investing in new capacity.

Following Pindyck (1988), we can decompose firm value into the value of assets in place (that allow the firm to produce $Q_i = \frac{Q}{n}$ units of output) and the value of growth options to increase output. Each growth option allows the firm to produce an extra unit of output by paying the cost I. However, the increase in output that follows investment reduces the output price (see equation (1)) and the value of assets in place. Growth options may thus increase or decrease firm value depending on which effect dominates. (As we show below, the net effect of growth options on firm value depends on the number of firms in the industry.) In Appendix A, we solve for the optimal investment strategy in the symmetric industry equilibrium and show that firm value can be expressed as:

$$V_n(Y,Q) = \frac{Q}{n}\left[\underbrace{\frac{YQ^{-\frac{1}{\gamma}}}{\delta} - \frac{c}{r}}_{\substack{\text{Value of one unit of output} \\ \text{when total output is fixed}}} + \underbrace{\frac{\gamma}{\gamma-\beta}\frac{1-\beta+n(\beta-\gamma)}{(\gamma n-1)(\beta-1)}\left(I+\frac{c}{r}\right)\left(\frac{Y}{Y_n^*(Q)}\right)^{\beta}}_{\substack{\text{Effects of growth options} \\ \text{on the value of one unit of output}}} \right], \quad (2)$$

[5] As in Carlson, Fisher, and Giammarino (2004) or Lambrecht, Pawlina, and Teixeira (2016), we do not consider the option for the firm to scale down operations when profitability deteriorates. Extending the model in this direction would significantly complexify the analysis without changing our main prediction that competition decreases option skew.

where[6]

$$\beta = \frac{1}{2} - \frac{r-\delta}{\sigma^2} + \sqrt{\left(\frac{1}{2} - \frac{r-\delta}{\sigma^2}\right)^2 + \frac{2r}{\sigma^2}} > 1,$$

and $Y_n^*(Q)$ is the value of the demand shock at which the firm invests, defined in equation (A1). The first term on the right hand side of this equation (i.e. $\frac{Q}{n}(YQ^{-\frac{1}{\gamma}}/\delta - c/r)$) is the present value of selling a fraction $\frac{1}{n}$ of total output forever and captures the value of assets in place when firms cannot increase output. The second term reflects the effects of changing output on this present value via new investment and the value of growth options. This term is negative when $n > \frac{\beta-1}{\beta-\gamma}$ as the endogenous capacity changes following an increase in demand have value consequences that exceed the value of the firm's growth options. That is, when firms have the option to add capacity, investment implies that the range of prices facing a competitive firm is bounded, which reduces firm value when competition is strong enough.

In equilibrium, firms invest and total output increases only when $Y_t = Y_n^*(Q) \equiv \overline{P}_n Q_t^{\frac{1}{\gamma}}$ where

$$\overline{P}_n = \frac{\gamma n}{\gamma n - 1} \frac{\beta}{\beta - 1} \delta \left(I + \frac{c}{r}\right). \tag{3}$$

That is, in an interval of time when no investment takes place, total capacity is fixed, so the price is proportional to the industry shock and $dP_t = dY_t$. When the output price reaches $\overline{P}_n$, capacity is added, total output increases and the price is immediately brought back to a slightly lower level so that the threshold $\overline{P}_n$ becomes an upper reflecting barrier for the output price process. Figure 1 plots the dynamics of the equilibrium output price when n firms are active in the industry.

Insert Figure 1 Here

The reflecting barrier decreases with the number of firms in the industry, in that $\overline{P}_m < \overline{P}_n$ for all $m > n$, so that the frequency of endogenous capacity changes increases with competition.

[6] As in Grenadier (2002) and Aguerrevere (2009), we assume that $\gamma < \beta$ to ensure the existence of an equilibrium. When this condition does not hold, future supply increases translate into an infinitely negative firm value, preventing the existence of the industry.

In the industry equilibrium with n firms, both the output price and total output vary through time as firms optimally invest in new capacity. Because the firm invests when the level of demand reaches a new high, the process of equilibrium output can be written as

$$Q_t = \max\left[Q_0, \left(\frac{M_t}{\overline{P}_n}\right)^{\gamma}\right] \tag{4}$$

where Q_0 is the initial output and $M_t \equiv \sup\{Y_s : 0 \le s \le t\}$ is the running maximum of the demand shock at time t. This also implies that we can write the equilibrium output price as

$$P_t = Y_t Q_t^{-\frac{1}{\gamma}} = Y_t \min\left[Q_0^{-\frac{1}{\gamma}}, \left(\frac{M_t}{\overline{P}_n}\right)^{-1}\right]. \tag{5}$$

Equations (4) and (5) show that we can express the output price and total output as functions of the industry shock and its running maximum. The price at time 0 of a European option maturing at time t can then be written as:

$$C_n(Y, M, 0, t) = \int_0^{\infty}\int_0^{\infty} e^{-rt}\frac{1}{N_t}\left[V_n(y,m) - K\right]^{+}\mathbb{P}(Y_t \in dy, M_t \in dm | Y_0 = Y, M_0 = M)$$

where N_t is the number of shares at time t, $V_n(y,m)$ is firm value expressed as a function of the industry shock and its running maximum, and $\mathbb{P}(Y_t \in dy, M_t \in dm|Y_0 = Y, M_0 = M)$ is their joint law at time t given starting values Y and M at time 0.[7] (A closed-form solution for this joint law is provided in the Appendix.)

While demand shocks are the only source of risk in this model, stock return volatility also depends on operating leverage and investment, both of which are affected by product market competition. Using equation (2), we can analyze the effects of competition on stock return volatility. Notably, an application of Itô's lemma implies that, for any given level of total output Q, stock return volatility is given by:

$$\sigma_{V_n}(Y, Q) \equiv \frac{1}{V_n(Y,Q)}\frac{\partial V_n(Y,Q)}{\partial Y}\sigma Y.$$

This leads to the following result:

[7] When there is investment, we need to keep track of the number of shares because firms finance investment by issuing new shares. This potential change in the number of shares is ignored in Toft and Prucyk (1997).

Proposition 1 (Competition and option skew) *For any given level of total output Q, stock return volatility $\sigma_{V_n}(Y,Q)$ is given by:*

$$\sigma_{V_n}(Y,Q) = \left[1 + \underbrace{\frac{\frac{c}{r}}{\frac{YQ^{-1/\gamma}}{\delta} - \frac{c}{r} + \frac{\gamma}{\gamma-\beta}\Omega(n)}}_{\substack{\text{Operating} \\ \text{leverage effect}}} - \underbrace{\frac{\frac{\gamma(\beta-1)}{\beta-\gamma}\Omega(n)}{\frac{YQ^{-1/\gamma}}{\delta} - \frac{c}{r} + \frac{\gamma}{\gamma-\beta}\Omega(n)}}_{\substack{\text{Supply} \\ \text{effect}}}\right]\sigma, \tag{6}$$

where $\Omega(n) \equiv \frac{1-\beta+n(\beta-\gamma)}{(\gamma n-1)(\beta-1)}\left(I + \frac{c}{r}\right)\left(\frac{Y}{Y_n^*(Q)}\right)^{\beta}$. *Stock return volatility displays an endogenous, negative correlation with stock returns when* $n > \frac{\beta-1}{\beta-\gamma}$ *in that*

$$\frac{\partial\sigma_{V_n}(Y,Q)}{\partial Y} = \frac{\frac{YQ^{-1/\gamma}}{\delta}\frac{\gamma(\beta-1)^2}{\gamma-\beta}\Omega(n) - \frac{c}{r}\left[\frac{YQ^{-1/\gamma}}{\delta} + \frac{\gamma\beta^2}{\gamma-\beta}\Omega(n)\right]}{YQ^{-1/\gamma}\left[\frac{YQ^{-1/\gamma}}{\delta} - \frac{c}{r} + \frac{\gamma}{\gamma-\beta}\Omega(n)\right]^2}\sigma < 0. \tag{7}$$

Equation (6) in Proposition 1 shows that, in a model with competition, stock returns are characterized by an endogenous stochastic volatility function that depends on a set of structural variables $\Sigma = \{r, \sigma, \delta, I, c, K, n\}$. Competition has two distinct effects on stock return volatility. First, by reducing profit margins and firm value, competition increases operating leverage and stock return volatility. This operating leverage effect is captured by the second term in the square bracket of equation (6).[8] Second, competition affects the optimal exercise of growth options and the effects of investment on the risk of assets in place. Indeed, on the one hand, the possibility for firms to invest creates growth options, which are riskier than assets in place (due to their implicit leverage). On the other hand, investment buffers the effects of demand shocks on equity value and reduces stock return volatility. Competition affects both channels by reducing the value of growth options and increasing the size and frequency of endogenous capacity changes that follow increases in demand. This (endogenous) supply effect is captured by the third term in the square bracket of equation (6). Because of these two opposing operating leverage and supply effects, competition may increase or decrease stock return volatility, a point first made by Aguerrevere (2009).[9]

[8]The term $\Omega(n)$ represents the value of changing output per unit of output, as captured in the second term of equation (2). It is immediate to show that $\frac{\partial\Omega(n)}{\partial n} = I\frac{(n-1)\beta}{n(\gamma n-1)^2}\left(\frac{Y}{Y_n^*(Q)}\right)^{\beta} \geq 0$. That is, an increase in competition decreases firm value and increases operating leverage.

[9]Consistent with this result, an early empirical study by Hou and Robinson (2006) finds that equity returns

A second implication of the model illustrated by equation (7) is that the operating leverage effect gets weaker while the supply effect gets stronger as the output and stock prices increase, implying that stock return volatility displays a negative correlation with (realized) stock returns (as in e.g. Heston (1993), Bates (2000), and Pan (2002) in which this relation is exogenously postulated). This in turn implies a negative option skew in that volatility decreases with the moneyness of the option (see e.g. Heston (1993; pp336-338) for a detailed discussion of the relation between the leverage effect—i.e. a negative correlation between stock returns and stock returns volatility—and the option skew). In addition, because the value $\Omega(n)$ of changing output per unit of output in (6) and (7) increases with n, we have that:

$$\frac{\partial \sigma_{V_n}(Y,Q)}{\partial Y} > \frac{\partial \sigma_{V_m}(Y,Q)}{\partial Y} \tag{8}$$

for all $m > n$, implying that an increase in the intensity of product market competition leads to a decrease in option skew. In our model, the negative relation between stock prices and stock return volatility follows from the fact that equity value $V_n(Y,Q)$ is an increasing and concave function of demand (and, as a result, of the output price) when competition is strong enough, i.e. when $n > \frac{\beta-1}{\beta-\gamma}$. Thus, changes in the volatility of stock returns are negatively correlated with stock price movements (due to changes in the output price): volatility tends to rise in response to bad news, and to fall in response to good news.

To illustrate the effects competition on option skew, assume first that there is no operating leverage (i.e. $c = 0$) so that the only channel at work is the supply channel. In this case, we have using equation (7):

$$\frac{\partial \sigma_{V_n}(Y,Q)}{\partial Y} = -\frac{\gamma\delta(\beta-1)^2}{\beta-\gamma}\frac{\Omega(n)}{[YQ^{-1/\gamma} - \frac{\delta\gamma}{\beta-\gamma}\Omega(n)]^2}\sigma. \tag{9}$$

It is immediate to verify that $\Omega(n)$ is positive and stock return volatility is negatively related to stock returns when $n > \frac{\beta-1}{\beta-\gamma}$, that is when competition is sufficiently strong. In addition

are lower in more concentrated industries, where concentration is measured using Compustat-based measures. A recent study by Gu (2016) also finds that firms in competitive industries earn higher expected returns than firms in concentrated industries, especially among R&D-intensive firms. By contrast, Bustamante and Donangelo (2017) find using different measures of concentration and markups a negative relation between product market competition and equity returns. Hoberg and Phillips (2010) show more pronounced industry booms and busts in more competitive industries.

and as discussed above, because $\Omega(n)$ increases with the number n of firms in the industry, the volatility skew is negatively related to the intensity of product market competition.[10]

Figure 2 plots the volatility of stock returns as a function of the level of demand (and therefore the output price) when there is no operating leverage. In this figure, we take values for the model parameters that are in line with those in Grenadier (2002) and Aguerrevere (2009). Specifically, the risk-free rate r is set to 5%, the growth rate and volatility of the demand shock are set to $r - \delta = 1\%$ and $\sigma = 20\%$, the cost of investment is set to $I = 1$, operating leverage is set to $c = 0$, and the elasticity of demand is set to $\gamma = 1.5$.

Insert Figure 2 Here

Consistent with equation (9), Figure 2 shows that for a monopolist stock return volatility increases with the level of demand as the firm's growth options (which are riskier than assets in place) get more in the money and, therefore, represent a larger fraction of total firm value. As competition increases, the value of growth options decreases and the main effect of investment is to reduce the risk of assets in place by buffering demand shocks. When the number of firms satisfies $n > \frac{\beta-1}{\beta-\gamma}$ (which is equivalent to $n > 2$ using the calibration of Aguereverre (2009), $n > 3$ using our calibration, or $n > 4$ using that in Grenadier (2002)), volatility is negatively related to stock returns and the greater the intensity of product market competition, the more negative this relation. In a perfectly competitive industry, the value of growth options is zero and volatility tends to zero as the output price approaches the reflecting barrier $\overline{P}_\infty$.

Figure 3 plots the volatility of stock returns as a function of the level of demand when there is operating leverage (i.e. assuming the same parameter values as in Figure 2 but with $c = 0.1$) and shows that in this case volatility is decreasing with the stock price, independently of the number of firms in the industry. This is due to the operating leverage effect, which becomes weaker as the stock price increases, causing stock return volatility to decrease. As in Figure 2, the decrease in volatility due to an increase in stock prices gets stronger as competition increases. Lastly, while the investment effect implies that additional competition leads to lower equity risk in Figure 2, the operating leverage effect implies that additional competition

[10] In this case, stock return volatility satisfies $\lim_{Y\to 0}\sigma_{V_n}(Y,Q) = \sigma$ and $\lim_{n\to+\infty}\sigma_{V_n}(Y_n^*(Q),Q) = 0$.

leads to higher equity risk in Figure 3, consistent with equation (6).

Insert Figure 3 Here

Our comparative statics have so far assumed that the level industry output was independent of the number of firms in the industry.[11] Under this assumption, the investment threshold $Y_n^*(Q)$ decreases with n. We can equivalently show how competition affects industry output. Notably, we have using equations (3) and (4) that for any number of firms n, total output at time $t > 0$ is given by:[12]

$$Q_t^n = \left[\frac{n\gamma - 1}{n(\gamma - 1)}\right]^{\gamma} Q_t^1.$$

As shown by this equation, an increase in the number of firms increases total output. This in turn leads to a decrease in output prices and to an increase in operating leverage and a decrease in the value of growth options. Figure 4 plots the volatility of stock returns as a function of the value of the demand shock when recognizing the effects of the number of firms on total output, assuming the same parameter values as in Figure 3. An important difference with Figure 3 is that the output price decreases and operating leverage increases with the number of firms in the industry. When n is low (e.g. $n = 1$), stock return volatility is mostly driven by the value of growth options and, as a result, it can again be positively related to

[11]This implies notably that current output price does not depend on the number of firms in the industry. Note however that these comparative statics reflect the effects of competition on the volatility of the output price P. Notably, in our model with competition, the dynamics of the output price are given by:

$$dP_t = (r - \delta)P_t dt + \sigma P_t dW_t - dU_t,$$

where the right-continuous, nonnegative, and non-decreasing process $U = (U_t)_{t \geq 0}$ is defined by $U_t = \sup_{0 \leq s \leq t} \left[(P_s^0 - \overline{P}_n) \vee 0\right]$, where $P_t^0 = Y_t Q_0^{-\frac{1}{\gamma}}$ is the unregulated price process. Standard derivations show that the distribution function of the output price at time t, conditional on $P_0 = P$ is given by:

$$\Pr[P_t \leq p]$$
$$= \Phi\left(\frac{\ln(p/P) - (r - \delta - \sigma^2/2)t}{\sigma\sqrt{t}}\right) + \left(\frac{p}{\overline{P}_n}\right)^{\frac{2(r-\delta)-\sigma^2}{\sigma^2}} \Phi\left(\frac{\ln(p/\overline{P}_n) + \ln(P/\overline{P}_n) + (r - \delta - \sigma^2/2)t}{\sigma\sqrt{t}}\right)$$

for $p \leq \overline{P}_n$, where $\Phi(z) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{z} e^{-\frac{1}{2}y^2} dy$ is the CDF of the standard Normal distribution. This in turn implies that all moments of the output price (including its volatility) are affected by competition.

[12]This assumes that $Q_0^n = \left[\frac{n\gamma-1}{n(\gamma-1)}\right]^{\gamma} Q_0^1$ or that $Q_t^n > Q_0^n$. Using equation (5), it is also possible to show that the output price in an industry with n firms satisfies: $P_t^n = \frac{n(\gamma-1)}{n\gamma-1} P_t^1$.

stock returns. As the number of firms increases, operating leverage increases and the value of growth options decreases, leading to a negative relation between stock returns and stock return volatility. Also, as shown by the figure, the investment threshold for new capacity $Y_n^*(Q^n)$ is the same for any number of firms in the market.

Insert Figure 4 Here

Our main prediction is about the negative relation between the intensity of product market competition and the option skew. In the empirical analysis, option skew is defined as the model-free implied skewness (MFIS), which represents a non-parametric estimate of the skewness of the risk-neutral (stock price) density implied by individual stock option prices. Indeed, as discussed for example in Rubinstein (1994), there is a one-to-one mapping between the *risk-neutral* density function and the implied volatility curve. Negatively sloped volatility curves—i.e. negative correlation between stock prices and stock return volatility—correspond to negative skewness in the risk-neutral density (see e.g. Heston (1993), Bakshi, Cao, and Chen (1997), or Dennis and Mayhew (2005)). In Figure 5, we accordingly plot the skewness of log returns implied by our model under the risk neutral probability measure using the same parameters as in Figure 2.

Insert Figure 5 Here

According to (8) the effect of product market competition on the reduction (respectively increase) in volatility at high (respectively low) demand states is stronger when there are more firms in the industry. We therefore expect a negative relation between the option skew and the number of firms. The corresponding comparative statics result is presented in Figure 5, in which the relation between the risk neutral skew and the number of firms is negative. As the number of firms increases, the skew decreases and converges to its value in the perfectly competitive model in which there is no value of waiting to invest and firms invest in extra capacity as soon as the net present value of investment is zero.[13]

[13]An important simplification of the model is that we assume that the industry has a fixed number of firms. As a result, we ignore the possibility for firms to exit. Industries with a higher intensity of competition are more likely to experience exit of firms, which should affect the option skew. We thank an anonymous referee

In the following, we test the central prediction of the model that there should be a negative relation between option skew and competition in product markets.

2. Data

Our main data source is IvyDB Optionmetrics that has comprehensive coverage of U.S. equity options from 1996 onwards. We obtain the necessary accounting data from Compustat and return and price data from CRSP. We start by excluding all options with zero open interest as quotes for such options are less likely to contain any useful information. We then compute the option skew, our main variable of interest, for every underlying option in our dataset on every trading day. Option skew is defined as the model-free implied skewness (MFIS), which represents a non-parametric estimate of the skewness of the risk-neutral (stock price) density implied by individual stock option prices. Bakshi, Kapadia, and Madan (BKM 2003) showed that MFIS as of time t measured over the time period $[t, T]$ can be computed as

$$\mathrm{MFIS}(t,T) = \frac{e^{r(T-t)}W(t,T) - 3\mu(t,T)e^{r(T-t)}U(t,T) + 2(\mu(t,T))^3}{\left(e^{r(T-t)}U(t,T) - (\mu(t,T))^2\right)^{3/2}}, \tag{10}$$

where $\mu(t,T)$ is the risk-neutral expectation of the log return on the underlying stock from t to T given by:

$$\mu(t,T) = e^{r(T-t)} - 1 - \frac{e^{r(T-t)}}{2}U(t,T) - \frac{e^{r(T-t)}}{6}W(t,T) - \frac{e^{r(T-t)}}{24}X(t,T). \tag{11}$$

In equation (11), $U(t,T)$, $W(t,T)$, and $X(t,T)$ are the prices of the volatility, cubic, and quadratic contracts, respectively. The prices of these contracts are derived in BKM (2003) and are also provided in Appendix B together with the details on the numerical algorithm used to compute these prices.

We focus on the model-free skewness because it uses options with all available strikes, does not rely on any particular option pricing model, and is also the most commonly used skewness

for bringing this issue to our attention. Leahy (1993) considers a perfect competition model with entry and exit but in which firms have a fixed size and cannot invest. It is possible to show that competition also leads to negative option skew in this model. Details are available upon request from the authors.

measure in the option pricing literature.[14] In robustness tests we also use the scaled skew measure proposed by Toft and Prucyk (1997), defined as the difference between Black-Scholes implied volatilities of out-of-the-money calls and out-of-the-money puts, scaled by the average of implied volatilities of at-the-money puts and calls. Appendix C contains details on the construction of the scaled version of the skew.

For each firm on every trading day with available option data we construct the MFIS measure. We repeat this procedure for all available option maturities between one and twelve months. We exclude options with maturities longer than one year, because such options are usually more thinly traded and have higher bid-ask spreads. For any given maturity, we average the resulting skew values across all trading dates with available data within a calendar month. We then compute the average of the skew measure across option maturities with available data. This gives us our final skew measure, available at a monthly frequency.

Our main proxy for the intensity of competition is the product market fluidity measure developed by Hoberg, Phillips, and Prabhala (2014), available in the Hoberg and Phillips data library starting in 1997. This proxy is based on product descriptions from firm 10-Ks and captures the structure and evolution of the product space occupied by firms. In particular, it captures competitive threats faced by firms and the changes in rivals' products relative to the firm. In robustness tests, we use two alternative competition measures: the number of firms in SIC and NAIC industries and the Herfindahl concentration measure constructed using text-based network industry classification ("TNIC3HHI"), developed by Hoberg and Phillips (2016). The TNIC measure is also based on textual analysis of firm 10K product descriptions and uses pairwise similarity scores to classify firms into industries. TNIC3 aims at developing an industry classification that is in general "as coarse"as the standard SIC3 classification.

In addition to our main variables of interest that proxy for the degree of industry competitiveness, we also construct a set of control variables that might affect the pricing of options and option skewness. Following the literature (e.g. Dennis and Mayhew (2002), Boyer, Mitton, and Vorkink (2010), or Engle and Mistry (2014)), our first control variable is the implied

[14]We thank Pierre Collin-Dufresne and an anonymous referee for encouraging us to use this measure. The model-free skewness measure is used for example by Dennis and Mayhew (2002), Bali and Murray (2013), Bakshi, Kapadia, and Madan (2003), Conrad, Dittmar, and Ghysels (2013), DeMiguel, Plyakha, Uppal, and Vilkov (2013), Kelly and Jiang (2014), Schneider (2015), Amaya, Christoffersen, Jacobs, and Vasquez (2015), Byun and Kim (2016), Bekaert and Engstrom (2017), or Londono and Zhou (2017) among others.

volatility of at-the-money options (ATM IV). We use this implied volatility measure for two purposes: to measure the volatility of a firm's stock return and to compare our results using skewness to other studies. Also, product market competition works by increasing volatility at low demand states and reducing volatility at high demand states in our theoretical framework, leading to negative skewness. If there is additional (e.g. idiosyncratic) volatility not related to competition, then the relative change in total volatility due to competition will be lower in magnitude when this additional volatility component is relatively high. This calls for controlling for the level of implied volatility in our tests, both when we use the MFIS measure and the IV-based scaled measure of skewness.[15]

Toft and Prucyk (1997) and Geske, Subrahmanyam, and Zhou (2016) show theoretically and empirically that financial leverage affects the pricing of options and the volatility surface. We therefore include market leverage as a control variable. Market leverage is defined as the book value of debt divided by the sum of the book value of debt and the market value of equity. Bakshi, Kapadia, and Madan (2003) develop a model in which return skewness of an individual stock depends on the skewness of the market return, the market exposure (beta), as well as the skewness of the idiosyncratic component. We therefore add idiosyncratic and market skewness constructed from daily returns and market betas as control variables. We compute betas using 36-month monthly rolling regressions of firm's excess returns on the excess return on the S&P500 index.

Grullon, Lyandres and Zhdanov (2012) show that firms with higher percentage value of growth options exhibit higher return skewness. To account for this potential effect on the volatility surface, we include market-to-book ratio and size as control variables. Higher market-to-book and smaller firms are likely to derive a higher percentage value from their growth options than from assets in place. Also, to the extent that (the inverse of) the market-to-book ratio proxies for financial distress, it should affect skewness in a manner similar to that discussed in Toft and Prucyk (1997). We define the market-to-book ratio as the ratio of

[15] Both MFIS and the scaled skewness measure are negative on average in our sample. However, there is a positive correlation between measures of industry competitiveness and ATM IV. Indeed, as shown in Proposition 1, product market competition may increase stock return volatility. Hence, not controlling for ATM IV would lead to a mechanical positive relationship between skewness and competition. It is therefore important to include ATM IV as a control.

market and book values of equity and size as the logarithm of the market value of equity. Because high momentum stocks may attract option traders wishing to speculate on subsequent price movement, we also include past six month equity returns as a control variable.

Table 1 presents the summary statistics of our main variables. Model free implied skewness (MFIS), our main variable of interest is negative on average, consistent with the general prediction of our model and also consistent with previous findings in the literature (see, for example, Bali and Murray (2013), Bakshi, Kapadia, and Madan (2003), Conrad, Dittmar, and Ghysels (2013)). Our concentration measures indicate that our sample spans firms along the whole competition spectrum—from those in highly competitive industries (fluidity measure of 34.2, text-based Herfindahl of 0.015, and 783 firms in the 3-digit SIC industry) to highly concentrated ones (fluidity measure of 0, text-based Herfindahl of 1, and 1 firm in the 3-digit SIC industry). The average firm has a fluidity measure of about 7.5 and TNIC3HHI of about 19%. The mean (median) firm market capitalization in our sample is 9.5 billion (2.2 billion) as firms with listed options tend to be larger in general. The summary statistics for other variables are generally in line with existing studies.

Insert Table 1 Here

As the universe of optionable stocks expands throughout our sample period, so does the set of stocks for which we are able to construct our skew measure. While it is only available for 965 stocks in 1996, this number grows to 1988 by 2014.

3. Empirical results

3.1. Option skew and competition

Our main hypothesis is for a negative relation between competition in product markets and the option skew. Option skew, our main variable, as well as control variables that use market prices and returns are available at a monthly frequency. However, fluidity, our main proxy for competitive threats, as well as the alternative competition measures are constructed at an annual frequency. Because both option skew and controls vary by month, we estimate our base empirical model using monthly observations. In the robustness section below we also estimate an alternative annual specification.

To test our main hypothesis, we run panel regressions of our option skew measure on proxies for the intensity of product market competition. Notably, we estimate the following model:

$$Skew_{i,t} = \alpha + \beta_1 Competition_{i,t-1} + \beta_2 Y_{i,t-1} + v_t + \epsilon_{i,t}, \tag{12}$$

where the subscripts i and t represent firm and time, respectively. Equation (12) relates the option skew to the intensity of competition. $Competition_{i,t-1}$ is the competition measure for firm i, as of the previous month.[16] Our main focus is on the coefficient estimate β_1. The set of control variables $Y_{i,t-1}$ includes variables that are commonly believed to affect option skew that are discussed above. These include the at-the-money implied volatility, financial leverage, past cumulative six month return, the market-to-book ratio, the logarithm of market capitalization, market beta, and idiosyncratic and market return skewness.

We include time fixed effects v_t to account for potential aggregate shocks that affect options market in general (for example, one can argue that the skew might take different shapes in recessions versus expansions). Because both the option skew and product market fluidity, our main competition measure, are defined at the firm level, we cluster standard errors by firm to control for potential serial correlation in residuals.[17] We use product market fluidity developed in Hoberg, Phillips, and Prabhala (2014) as our main competition measure. We believe it is particularly relevant in our setting as it captures competitive threats from the product market space. In robustness tests below we use alternative industry concentration measures, in particular, text-based Herfidahl index, TNIC3HHI, and the number of firms in SIC and NAICS industries.

[16] We follow common practice in the literature and skip six months when merging annual COMPUSTAT data and our competition data with monthly CRSP and option data.

[17] Our results remain statistically significant if we cluster standard errors by 2-,3-, or 4-digit SIC and NAICS industries.

Results from our regressions are presented in Table 2.

Insert Table 2 Here

Consistent with our main hypothesis, product market fluidity, our main proxy for competition, is negative and highly significant in all specifications. The effect of competition is also economically meaningful: Keeping everything else equal, a firm in a perfectly competitive industry has a model-free skewness measure approximately 15 basis points below that of a firm in a monopoly industry. Consistent with Dennis and Mayhew (2002), the coefficients on the level of implied volatility are positive and statistically significant. Consistent with the findings of Toft and Prucyk (1997), coefficients on financial leverage are negative and statistically significant. Coefficients on beta and size are both negative, suggesting that small, high-beta stocks tend to exhibit more negatively skewed cross-section of option prices. As expected, the at-the-money implied volatility is positive and highly significant, further validating our arguments for including it as a control variable.

3.2. Alternative competition measures

While product market fluidity, our main proxy for the degree of industry competitiveness, is particularly well suited to reflect potential competitive threats, we perform a number of robustness tests for our main hypothesis of the negative relation between product market competition and option skew while using alternative concentration measures.

Our first such measure is the TNIC3HHI of Hoberg and Phillips (2016). This measure was created using text based analysis of firm 10K filings to compute firm-by-firm pairwise similarity scores. The TNIC industry classification is then constructed with same degree of coarseness as the standard SIC3 classification. The TNIC3HHI is then computed as the Herfindahl index on the TNIC3 industry classification. Our second alternative competition measure is based on the number of firms in the industry. In particular, we use 3 and 4-digit SIC and NAICS industry definitions. Clearly, industries with more firms based on either SIC or NAICS industry classification are likely to be subject to more intense competition, on average. Also, there is substantial variation in the number of firms in SIC3(4) and NAICS3(4) industries across industries, and also to some degree over time. For example, the most concentrated SIC3 industry in our sample contains only one firm, while least concentrated one contains 783 firms. The corresponding numbers for the NAICS3 classification are 1 and 839, respectively.

To gauge the effect of these alternative competition measures on the option skew, we repeat our analysis in Table 2 while replacing product market fluidity with TNIC3HHI and the number of firms in the SIC3/SIC4/NAICS4/NAICS4 industry. Table 3 reports the results from these tests. Panel A of Table 3 uses TNIC3HHI as the measure of competition, while Panel B uses the number of firms.

Insert Table 3 Here

The evidence in Table 3 demonstrates the robustness of our main result to the usage of alternative competition measures. Both TNIC3HHI and the number of firms are highly significant in most specifications (marginally significant in the others) and have the predicted signs. Importantly, the positive sign on TNIC3HHI is expected because it is inversely related to industry competitiveness. The results are also economically significant. For example, one standard deviation decrease in concentration based on the number of firms in the SIC3/NAIC3 industry, results in a decrease in the model-free skewness measure by about three percentage points relative to its mean. On the other hand, moving from the most concentrated industry in our sample to the most competitive one (and keeping everything else constant) results in a decrease in MFIS of about 7 basis points (which constitutes about 18% of its mean value). The coefficients on control variables remain similar to those in our base case regressions reported in Table 2.

3.3. Barriers to entry

Competitive threats are likely to be stronger in industries with lower barriers to entry. Therefore, the effect of product market competition on option skew is also likely to be stronger in such industries. On the other hand, the probability of entry during the maturity of an option is lower in industries with high entry costs and, therefore, we expect the volatility reduction due to potential entry to be attenuated. We argue that capital intensive industries pose stronger barriers to entry. We follow Campello and Larrain (2016) and Kung and Kim (2017) and proxy capital intensity by asset tangibility, defined as the ratio of gross plant property and equipment and total assets.

To examine the effect of entry costs on options skewness, we run panel regressions of option skew on fluidity akin to those in Table 2, while augmenting our regression specification by including tangibility and its interaction with fluidity. We then expect to see a positive coefficient on the interaction term.

Insert Table 4 Here

Results from this exercise are reported in Table 4. Consistent with our conjecture, coefficients on the interaction terms of tangibility and fluidity are positive and highly statistically significant in all regressions specifications. This indicates a stronger effect of product market fluidity on MFIS in firms with lower barriers to entry (as proxied by tangibility). Tangibility itself, however, does not exhibit a significant relation to the option skew.

3.4. Alternative measure of option skew

We next explore the robustness of our main results to an alternative measure of the option skew. Following Toft and Prucyk (1997), we define option skew as the difference between Black-Scholes implied volatilities of out-of-the-money calls and out-of-the-money puts, scaled by the average of implied volatilities of at-the-money puts and calls. We provide details on the construction of this measure in Appendix B.

The results from regressions with this alternative skewness measure are presented in Table 5. As in Table 2, we cluster standard errors by firm to take care of potential serial correlation of residuals and include time fixed effects to account for potential economy-wide shocks to the option skew.

Insert Table 5 Here

The evidence in Table 5 displays the robustness of our main results to using the scaled implied volatility measure of Toft and Prucyk (1997) as a proxy for skewness. Coefficients on the fluidity measure are negative and significant in all specifications. They also exhibit a non-trivial degree of economic importance: a one standard deviation increase in industry competitiveness, as measured by fluidity, results in a 20% drop in the scaled skew measure relative to its mean.

3.5. Recessions versus expansions

Competitive entry threats are likely to be weaker in recessions than in expansions. Also, recessions are usually accompanied by periods of heightened volatility. It is therefore interesting to examine the effect of competition in product markets on the option skewness separately in recessions and expansions. Because of reduced threats of entry in recessions, one might expect a weaker effect in recessions relative to expansions, when new entry as well as investment by rival firms is less likely.[18]

To further examine the role of volatility regimes in our findings, in addition to the recession-expansion splits, we also split our sample into periods of high and low volatility as proxied by the VIX being above or below its time-series median.

The results from these sample splits are presented in Table 6. Specifications (1) and (2) report results in recessions, while specifications (3) and (4) provide results for expansions. We use NBER recession indicators to identify recessions and expansions. Specifications (5)-(8) report results from sample splits based on the high and low degree of overall uncertainty, as proxied by the VIX.

Insert Table 6 Here

The results in Table 6 indicate that product market fluidity has no effect on the model free skewness in recessions. This result is expected. First, less than 10% of our sample represent

[18] In a related paper, Hoberg and Phillips (2010) find that during industry booms systematic risk decreases more for firms in competitive industries than in concentrated industries and that during industry busts systematic risk decreases more for firms in concentrated industries than in competitive industries, consistent with the predictions of Aguerrevere (2009).

recession months. Second, as we argue above, competitive threats are subdued in recessions and hence we expect their effect on the skew to be weaker. While we do not have any specific predictions for the differential magnitudes of the competition effect in periods of high versus low aggregate volatility, the results in Table 6 show significant effect in both low-VIX and high-VIX subsamples, with the coefficients on product market fluidity being very similar in magnitude.

3.6. Annual frequency

As argued above, product market fluidity is constructed from annual statements and is therefore available at an annual frequency, while our main regression specification is based on monthly observations. As an additional robustness check, we average our option skew measure and control variables for each firm within a year and re-run our main tests on these annualized data. The results from these additional tests are presented in Table 7.

Insert Table 7 Here

The evidence in Table 7 demonstrates the robustness of our main results to these alternative specifications. Using annual data results in a sharp drop in the number of observations. However, coefficients on fluidity remain similar in magnitude and continue to remain highly statistically significant.

4. Competition and skew: Evidence from a natural experiment

To look deeper into the relation between product market competition and option skew, we take advantage of an exogenous shock to the competitiveness of the US manufacturing industries associated with granting a Permanent Normal Trade Relations ("PNTR") status to China in October 2000, which became effective upon China's accession to WTO in 2001. As Pierce and Schott (2016) point out, US imports from nonmarket economies like China are subject to relatively high tariff rates originally set under the Smoot-Hawley Tariff Act of 1930. These rates ("non-NTR rates") are substantially higher that the NTR rates enjoyed by WTO members. The case of China is unique as the United States had been applying the low NTR import tariffs rates to China since 1980. However, these rates required annual renewal and were subject to considerable political uncertainty. Without renewal, the US tariffs on Chinese goods would have jumped to the much higher non-NTR level. As Pierce and Schott (2016) argue, there was a high probability of revoking the low NTR tariffs applied to China with the average opposition to those rates in the House of 38%.

The change in China's PNTR status had two effects. First, it ended the uncertainty associated with annual renewals of China's NTR status and reduced the value of the option to wait for Chinese firms, thereby encouraging these firms to invest more in US-China trade. Second, it reduced the expected import tariffs applied to China by removing any possibility of returning to the higher non-NTR tariffs. Both effects lead to greater competition arising from Chinese imports and generated a positive shock to competitive forces within US manufacturing industries.

We analyze the effect of this exogenous shock to competition in two different ways. First, we use a difference-in-difference analysis to examine the resulting change in the option skew for firms in manufacturing industries (treated firms) versus firms in the other industries (control firms). Second, following Pierce and Schott (2016), we take advantage of the variation in tariffs across industries and study the relation between the skew and the *NTR Gap*, defined as the difference between industry's non-NTR and NTR rates.

Feenstra, Romalis, and Schott (2002) compute NTR gaps as the difference between the non-NTR and NTR import tariffs at the 8-digit Harmonized System (HS) level for manufacturing industries. Following Pierce and Schott (2016), we use the NTR gaps for 1999—the year before passage of PNTR in the United States. We use the concordance table also developed by Pierce and Schott (2016) to match HS codes to NAICs industries.

In our first test, to capture the effect of granting PNTR status to China on the option skew of US firms, we adopt a difference-in-difference methodology and define a *Post NTR* dummy that indicates whether or not an industry was subject to intensified competition with

China in month t. We set the *Post NTR* dummy to one in the months after October 2000 in manufacturing industries (i.e. industries with available data on import tariffs) and set it to zero before October 2000 in manufacturing industries and in all months in the other (non-manufacturing) industries. Our empirical specification has the following form:

$$Skew_{i,t} = \alpha + \beta PostNTR_{i,t} + \delta X_{i,t-1} + v_t + \eta_i + \varepsilon_{i,t},$$

where $Skew_{i,t}$ is the option skew of firm i in month t and $X_{i,t-1}$ is a vector of control variables used in our main tests. As is standard when implementing differences-in-differences analysis, we include firm fixed effects η_i to absorb time- invariant differences across firms and account for potential exogenous drivers of the skew at the firm level. We also include time fixed effects v_t to control for time-varying factors common to all firms and absorb potential impact of global time-varying economic conditions on the options market. To control for potential serial correlation in residuals, we cluster the standard errors at the firm level. Because we are interested in the effect of China's PNTR status on the skew we limit our sample to the three year period around the PNTR approval in October 2000.

The results from these tests are presented in Table 8. Consistent with our main hypothesis of a negative relation between competition and option skew, these results demonstrate a significant negative effect on the option skew of firms in manufacturing industries in all regression specifications. The results are also economically large and suggest that following China's entry into WTO and obtaining the PNTR status the model free implied skewness of firms in manufacturing industries (that were subject to intensified competition with Chinese imports) decreased by about 5 to 11 basis points relative to firms in non-manufacturing industries.

Insert Table 8 Here

In our second test, we follow Pierce and Schott (2016) and focus solely on manufacturing (treated) industries. We exploit the variation in the "tariff gap" defined as the difference between non-NTR and NTR tariff rates in an industry. The magnitude of the shock to competition intensity in an industry is likely to be higher when the tariff gap is larger as greater reductions in tariffs are likely associated with more aggressive penetration of China's products. We therefore expect a *negative* relation between the tariff gap and the resulting effect on the option skew. Our empirical specification for this test has the following form:

$$Skew_{i,t} = \alpha + \beta PostNTR_t \times NTRGap_i + \delta X_{i,t-1} + \upsilon_t + \eta_i + \varepsilon_{i,t},$$

where $NTRGap_i$ is the difference between the non-NTR rate to which the tariffs would have risen if annual renewal had failed and the NTR rate that was locked by granting China the PNTR status. As before, the *Post NTR* dummy is set to one for dates after October 2000 and to zero otherwise.

The results from the second test are presented in Table 9. These results demonstrate a negative and statistically significant relation between the NTR gap and subsequent decline in the option skew of firms in manufacturing industries. Firms in industries with the highest tariff gap experience a decline in the skew 18 to 33 basis points larger than those in industries with the lowest gap. This provides further evidence in support of a negative effect of product market competition on option skew, while addressing potential endogeneity concerns.

Insert Table 9 Here

In Appendix D, we follow Frésard (2010) and Frésard and Valta (2016) and focus on import tariff reductions in manufacturing industries that occurred between 1974 and 2005. Because import tariff reductions are likely associated with increased competitive threats, our model suggests that they should have negatively affect the skew in the option prices. Unfortunately, the Optionmetrics coverage of individual equity options starts in 1996, and the vast majority of tariff reductions occurred in 1970s and 1980s. This rends tests that involve options data inappropriate for studying the effect of import tariffs on the skew. We therefore follow Boyer, Mitton, and Vorkink (2010) and construct an alternative measure of stock return skewness that does not rely on the option data. The results presented in Table A1 of Appendix D provide additional evidence, based on alternative measures of skewness, in support of our main hypothesis of a negative relation between competition and option skew.

5. Conclusion

We show that competition in product markets is an important driver of the prices of financial options and of the option skew. We do so by modeling the effects of product market competition on the dynamics of output and equity prices and by showing that, as output and stock prices rise, investment by competitors becomes more likely, putting pressure on the equilibrium output price process and leading to a drop in the variance of stock returns. Symmetrically, as output and stock prices decrease, operating leverage increases, leading to an increase in equity risk that is stronger in more competitive environments. That is, we show that product market competition implies a specific stochastic process for the volatility of equity returns and produces a negative volatility skew in the prices of options on equity. To the best of our knowledge ours is the first paper that models the effects of product market competition on the stochastic process driving the volatility of equity returns and on the cross-section of option prices and option skew.

We proceed by empirically testing our main hypothesis for a negative relation between option skew and the intensity of product market competition. In this analysis, we use a large sample of individual U.S. equity options from 1996 to 2014 and two measures of option skew: the model-free implied skewness, which represents a non-parametric estimate of the risk-neutral expected stock-return skewness, and the difference between Black-Scholes implied volatilities of out-of-the-money calls and out-of-the-money puts, scaled by the average of implied volatilities of at-the-money puts and calls. We then test whether option skew is related to product market competition, as measured by product market fluidity, the text based Herfindahl-Hirschman Index, or the number of firms in SIC and NAIC industries. We find strong evidence in support of a negative relation. We also show that this effect is attenuated in industries with high barriers to entry or in recessions. We provide additional evidence from a shock to competitiveness due to granting a PNTR status to China in 2000. Overall, our analysis demonstrates the value of going beyond stock return data and using relevant information from firm-level option prices when trying to understand the relation between competition and equity risk and value.

Appendix

A. Competition and option skew in an imperfect competition model

In the model with imperfect competition, firm value is the solution to

$$V_n(Y,Q) = max_{\{Q_{i,t}:t>0\}}\mathbb{E}\left[\int_0^{+\infty} e^{-rt}\left(Q_{i,t}(Y_tQ_t^{-\frac{1}{\gamma}} - c)dt - IdQ_{i,t}\right)\right].$$

To determine this value, we first consider the value of investing in a marginal unit of capital in the symmetric industry equilibrium. Standard derivations show that the value $G_n(Y,Q)$ of the option to invest in a marginal unit of capital satisfies:

$$rG_n(Y,Q) = (r-\delta)YG_n'(Y,Q) + \frac{1}{2}\sigma^2Y^2G_n''(Y,Q),$$

which is solved subject to the value-matching and smooth-pasting conditions

$$G_n(Y_n^*(Q),Q) = \frac{n\gamma}{n\gamma-1}\frac{Y_n^*(Q)Q^{-\frac{1}{\gamma}}}{\delta} - \left(I+\frac{c}{r}\right)$$
$$G_n'(Y_n^*(Q),Q) = \frac{n\gamma}{n\gamma-1}\frac{Q^{-\frac{1}{\gamma}}}{\delta}.$$

where $Y_n^*(Q)$ is the equilibrium investment threshold and where we have used the fact that a marginal unit of capital produces a continuous flow of profit given by:

$$\pi(Y,Q) = \frac{n\gamma}{n\gamma-1}YQ^{-\frac{1}{\gamma}} - c.$$

Solving these equations yields:

$$Y_n^*(Q) = \frac{\gamma n}{\gamma n-1}\frac{\beta}{\beta-1}\delta\left(I+\frac{c}{r}\right)Q^{\frac{1}{\gamma}} \equiv \overline{P}_nQ^{\frac{1}{\gamma}}, \quad \text{(A1)}$$

where $\overline{P}_n$ is the output price triggering investment and

$$\beta = \frac{1}{2} - \frac{r-\delta}{\sigma^2} + \sqrt{\left(\frac{1}{2}-\frac{r-\delta}{\sigma^2}\right)^2 + \frac{2r}{\sigma^2}} > 1. \quad \text{(A2)}$$

Consider next the value of the firm $V_n(Y,Q)$. Given the optimal investment threshold $Y_n^*(Q)$, the value of the firm satisfies in the inaction region:

$$rV_n(Y,Q) = (r-\delta)YV_n'(Y,Q) + \frac{1}{2}\sigma^2Y^2V_n''(Y,Q) + \frac{Q}{n}\left(YQ^{-\frac{1}{\gamma}} - c\right). \quad \text{(A3)}$$

At the investment trigger, total output increases from Q to $Q+dQ$ and the firm pays the exercise price $\frac{I}{n}dQ$. As a result, firm value satisfies the value matching condition: $V_n(Y_n^*(Q),Q) = V_n(Y_n^*(Q),Q+dQ) - \frac{I}{n}dQ$. Dividing dy dQ and taking the limit as dQ, this value matching condition can be written in derivative form as:

$$\frac{\partial V_n(Y_n^*(Q),Q)}{\partial Q} = \frac{I}{n}. \tag{A4}$$

The solution to equation (A3) is given by

$$V_n(Y,Q) = A_n(Q)Y^\beta + \frac{Q}{n}\left(YQ^{-\frac{1}{\gamma}} - c\right),$$

where β is defined in equation (A2). Plugging this expression in equation (A4) yields

$$A_n'(Q) = \left[I + \frac{c}{r} - \left(\frac{\gamma-1}{\gamma}\right)\frac{\overline{P}_n}{\delta}\right]\left(\frac{\overline{P}_n^{-\beta}}{n}\right)Q^{-\frac{\beta}{\gamma}}$$

Integrating $A_n'(z)$ between Q and $+\infty$, the value of each firm can then be expressed as

$$V_n(Y,Q) = \frac{Q}{n}\left[\frac{YQ^{-\frac{1}{\gamma}}}{\delta} - \frac{c}{r} + \frac{\gamma Q}{\gamma-\beta}\left(I + \frac{c}{r} - \frac{(\gamma-1)Y_n^*Q^{-\frac{1}{\gamma}}}{\gamma\delta}\right)\left(\frac{Y}{Y_n^*}\right)^\beta\right]. \tag{A5}$$

Consider now the effects of competition on option prices. In the industry equilibrium with n firms, both the output price and total output vary through time as firms optimally invest in new capacity. As a result, firm value is given by equation (A5). Because the firm invests when Y_t reaches a new high, the process of equilibrium output can be written as

$$Q_t = \max\left[Q, \left(\frac{M_t}{\overline{P}_n}\right)^\gamma\right] \tag{A6}$$

where Q is the initial output and $M_t \equiv \sup\{Y_s : 0 \leq s \leq t\}$ is the running maximum of the demand shock at time t. This also implies that we can write the equilibrium output price as

$$P_t = Y_t Q_t^{-\frac{1}{\gamma}} = Y_t \min\left[Q^{-\frac{1}{\gamma}}, \left(\frac{M_t}{\overline{P}_n}\right)^{-1}\right]. \tag{A7}$$

Equations (A6) and (A7) imply that we can express the option price as a function of the industry shock and its running maximum. Notably, the price at time 0 of a European option maturing at time t is given by:

$$C_n(Y,M,0,t) = \int_0^\infty\int_0^\infty e^{-rt}\frac{1}{N_t}\left[V_n(y,m) - K\right]^+ \mathbb{P}(Y_t \in dy, M_t \in dm | Y_0 = Y, M_0 = M)$$

where N_t is the number of shares at time t, $V_n(y,m)$ is firm value expressed as a function of the industry shock and its running maximum and $\mathbb{P}(Y_t \in dy, M_t \in dm | Y_0 = Y, M_0 = M)$ is their joint law at time t given starting values Y and M at time 0. Using equation (A5) and the fact that $\gamma < \beta$, it is immediate to show that

$$V_n(y,m) = \frac{y \max\left[Q^{1-\frac{1}{\gamma}}, \left(\frac{m}{\overline{P}_n}\right)^{\gamma-1}\right]}{n\delta} + \frac{\gamma \min\left[Q^{1-\frac{\beta}{\gamma}}, \left(\frac{m}{\overline{P}_n}\right)^{\gamma-\beta}\right]}{n(\gamma-\beta)} \left(I + \frac{c}{r} - \frac{(\gamma-1)\overline{P}_n}{\gamma\delta}\right)\left(\frac{y}{\overline{P}_n}\right)^{\beta}.$$

Because total output does not change between time 0 and time t if the unregulated process does not reach a new maximum, we can rewrite the option price as

$$\begin{aligned} &C_n(Y,M,0,t) \qquad\qquad \text{(A8)} \\ &= \int_0^M e^{-rt} \left[V_n(y,M) - K\right]^+ \mathbb{P}(Y_t \in dy, T(M_0) > t | \, Y_0 = Y, M_0 = M) \\ &+ \int_M^\infty \int_0^m e^{-rt} \frac{1}{N_t} \left[V_n(y,m) - K\right]^+ \\ &\times \int_0^t \mathbb{P}(T(M_0) \in du | \, Y_0 = Y, M_0 = M) \mathbb{P}(Y_t \in dy, M_t \in dm | \, Y_u = M_u = M_0 = M). \end{aligned}$$

The first term on the right hand side of (A8) captures the option price if total output does not change before the option matures. The second term captures the option price if total output increases before the option matures due to the demand shock reaching a new high before time t. In this equation, $T(M_0)$ is the first time that Y reaches M_0: $T(M_0) = \inf\{s > 0 : Y_s \geq M_0\}$. The law $\mathbb{P}(Y_t \in dy, T(M_0) > t | \, Y_0 = Y, M_0 = M)$ is given by

$$\begin{aligned} &\mathbb{P}(\, Y_t \in dy, T(M_0) > t | \, Y_0 = Y, M_0 = M) \\ &\quad = \mathbb{P}(Y_t \in dy | \, Y_0 = Y) - \mathbb{P}(Y_t \in dy, M_t \geq M_0 | \, Y_0 = Y, y \leq M_0 = M) \\ &\quad = \frac{1}{y\sigma\sqrt{2\pi t}} e^{-\frac{(r-\delta-\sigma^2/2)^2 t}{2\sigma^2} + \frac{r-\delta-\sigma^2/2}{\sigma^2}\log\frac{y}{Y}} \times \left[e^{-\frac{1}{2\sigma^2 t}\log^2\frac{y}{Y}} - e^{-\frac{1}{2\sigma^2 t}\log^2\frac{M^2}{yY}}\right] dy. \end{aligned}$$

where the last equality follows from Borodin and Salminen (2002, chapter 9). Lastly, the laws $\mathbb{P}(T(M_0) \in du | \, Y_0 = Y, M_0 = M)$ and $\mathbb{P}(Y_t \in dy, M_t \in dm | \, Y_u = M_u = M_0 = M)$ can be computed as (see e.g. Jeanblanc, Yor, and Chesney (2009, chapter 3))

$$\mathbb{P}(T(M_0) \in du | \, Y_0 = Y, M_0 = M) = \frac{1}{\sigma\sqrt{2\pi u^3}} \log\frac{M}{Y} e^{-\frac{1}{2\sigma^2 u}\left(\log\frac{M}{Y} - (r-\delta-\sigma^2/2)u\right)^2} 1_{\{u>0\}} du,$$

and

$$\mathbb{P}(Y_t \in dy, M_t \in dm | Y_u = M) = \frac{2}{\sigma^3 \sqrt{2\pi(t-u)^3}} \frac{\log \frac{m^2}{yM}}{my} e^{-\frac{\log^2 \frac{m^2}{yM}}{2\sigma^2(t-u)} + \frac{r-\delta}{\sigma^2} \log \frac{y}{M} - \frac{(r-\delta)^2(t-u)}{2\sigma^2}} dmdy.$$

B. Details on the construction of MFIS

In this Appendix, we present numerical details on the construction of the model-free implied skewness measure, MFIS. Denote by $S(t)$ the underlying stock price at time t and by $C(t,T,K)$ and $P(t,T,K)$ the prices of call and put options with maturity date T and exercise price K. We start off with equations (10) and (11). The prices of the volatility, $U(t,T)$, cubic, $W(t,T)$, and quadratic, $X(t,T)$, contracts are given by (see Bakshi, Kapadia, and Madan, 2003):

$$U(t,T) = \int_{S(t)}^{\infty} \frac{2\left(1 - \ln\left[\frac{K}{S(t)}\right]\right)}{K^2} C(t,T,K)dK + \int_{0}^{S(t)} \frac{2\left(1 + \ln\left[\frac{S(t)}{K}\right]\right)}{K^2} P(t,T,K)dK; \quad \text{(B1)}$$

$$W(t,T) = \int_{S(t)}^{\infty} \frac{6\ln\left[\frac{K}{S(t)}\right] - 3\left(\ln\left[\frac{K}{S(t)}\right]\right)^2}{K^2} C(t,T,K)dK$$
$$- \int_{0}^{S(t)} \frac{6\ln\left[\frac{S(t)}{K}\right] + 3\left(\ln\left[\frac{S(t)}{K}\right]\right)^2}{K^2} P(t,T,K)dK;$$

$$X(t,T) = \int_{S(t)}^{\infty} \frac{12\left(\ln\left[\frac{K}{S(t)}\right]\right)^2 - 4\left(\ln\left[\frac{K}{S(t)}\right]\right)^3}{K^2} C(t,T,K)dK \quad \text{(B2)}$$
$$+ \int_{0}^{S(t)} \frac{12\left(\ln\left[\frac{S(t)}{K}\right]\right)^2 + 4\left(\ln\left[\frac{S(t)}{K}\right]\right)^3}{K^2} P(t,T,K)dK.$$

To compute the expressions in (B1)-(B2), we apply additional filters to the option data. First, we discard observations with zero bid quotes and those with the bid price exceeding the ask. We then retain only out-of-the money puts and calls as those are required in (B1)-(B2). We also make sure that the no-arbitrage conditions hold for puts and calls. In particular, we remove observations with ask quotes for calls less than the difference between the underlying price and the strike, and with ask quotes for puts less than the difference between the strike and the underlying. We then compute option prices at the midpoint of the bid-ask spread. Finally, we check that all call(put) prices are decreasing(increasing) in the strike price. Thus, we discard all observations for a given stock/date/maturity if for some i and j, such that $K_j > K_i$, $C(K_j) > C(K_i)$ or $P(K_j) < P(K_i)$.

We follow Dennis and Mayhew (2002), Bali and Murray (2013), Conrad, Dittmar, and Ghysels (2013), and Bali, Hu, and Murray (2017) and use trapezoidal approach when numerically approximating integrals in (6)-(8). As in Bali and Murray (2013), we require that a minimum of two OTM puts and two OTM calls have valid prices. If not enough data are available, the observation is discarded.

C. Details on the construction of the scaled skew measure

We follow Toft and Prucyk (1997) when constructing the scaled skewness measure. In particular, on every trading date for each stock and option maturity, we identify an OTM call option with a strike K_a such that $0 \leq \frac{K_a - S(t)}{S(t)} \leq 0.1$. Out of all options that satisfy this condition we choose the one closest to 10% OTM. We repeat this procedure for strikes $0.1 \leq \frac{K_b - S(t)}{S(t)} \leq 0.2$ and again identify an option with a strike K_b that is closest to 10% OTM while satisfying this condition. We then use trapezoidal approximation to evaluate the implied volatility of a 10% OTM call option:

$$IV_{OTM\_Call} = IV(C(S(t), K_a)\frac{K_b - 0.1}{K_b - K_a} + IV(C(S(t), K_b)\frac{0.1 - K_a}{K_b - K_a}.$$

We use a similar procedure to determine the OTM put implied volatility, IV_{OTM_Put}. The scaled skew is then defined as

$$SS = \frac{IV_{OTM\_Call} - IV_{OTM\_put}}{0.5(IV_{ATM\_Call} + IV_{ATM\_put})},$$

where IV_{ATM_Call} and IV_{ATM_put} are implied volatilities of the call and the put, respectively, with the strikes closest to the underlying price, conditional on the strikes being within a 5% range relative to the underlying.

D. The effect of import tariff reductions

In this Appendix we follow Frésard (2010) and Frésard and Valta (2016) and focus on import tariff reductions in manufacturing industries that occurred between 1974 and 2005. Import tariffs impose barriers to entry for foreign rival firms and a significant reduction in the tariff represents a competitive threat faced by domestic firms. Consistent with this argument, Frésard and Valta (2016) found that incumbents reduce investments in response to tariff reductions and that the investment reductions concentrate in markets in which competitive actions are strategic substitutes.

Because import tariff reductions are likely associated with increased competitive threats, our model suggests that they should have negatively affect the skew in the option prices. Unfortunately, the Optionmetrics coverage of individual equity options starts in 1996, and the vast majority of tariff reductions occurred in 1970ies and 1980ies. This rends tests that involve options data inappropriate for studying the effect of import tariffs on the skew. We therefore construct an alternative measure of stock return skewness that does not rely on the option data. In particular, we follow Boyer, Mitton, and Vorkink (2010) and construct a measure of expected skewness by estimating a cross-sectional model with historical skewness and additional controls. This expected skewness measure is forward-looking and therefore is the best available alternative to the skewness measure constructed directly from options. Boyer et al. (2010) focus on the effect of expected idiosyncratic skewness on stock returns. Because competitive threats arising from tariffs reductions can potentially have both idiosyncratic and market components, we use both expected idiosyncratic and expected total skewness as forward looking skew measures and study how they react to changes in import tariffs.

We start by estimating a cross-sectional model of skewness akin to that developed in Boyer et al. (2010). We run monthly cross-sectional regressions of the following specification:

$$IdSkew_{i,t} = \beta_{0,t} + \beta_{1,t} IdSkew_{i,t-T} + \beta_{2,t} TotSkew_{i,t-T} + \beta_{3,t} IdVol_{i,t-T} + \beta_{4,t-T} TotVol_{i,t-T} + \lambda_t X_{i,t-T} + \epsilon_{i,t}, \quad \text{(D1)}$$

$$TotSkew_{i,t} = \beta_{0,t} + \beta_{1,t} IdSkew_{i,t-T} + \beta_{2,t} TotSkew_{i,t-T} + \beta_{3,t} IdVol_{i,t-T} + \beta_{4,t-T} TotVol_{i,t-T} + \lambda_t X_{i,t-T} + \epsilon_{i,t}, \quad \text{(D2)}$$

where $IdSkew_{i,t}$ and $TotSkew_{i,t}$ are the measures of idiosyncratic and total skewness for firm i in month t, and $IdVol_{i,t}$ and $TotVol_{i,t}$ are the idiosyncratic and total volatilities, respectively. We compute total volatility and total skewness measures as the second and the third moments of the distribution of daily returns in month t. Measures of idiosyncratic skewness and idiosyncratic volatility are based on the residuals from daily regressions of returns on the Fama and French (1993) three factors. Because in our main tests we use option maturities between one and twelve months, in this section we set T to six months to match the average option maturity.

Following Boyer et al. (2010), we use size (logarithm of market cap), market-to-book ratio, average daily turnover within a month, past twelve month return, and SIC2 industry dummies as additional control variables. We then use fitted values from regression models (D1) and (D2) as proxies for expected idiosyncratic and total skewness.

In the next step, we follow Frésard (2010) and Frésard and Valta (2016) and identify industry-years with significant tariff reductions. Similarly to Fresard (2010), we define a significant tariff reduction as an event in an industry-year when the negative tariff change is three times larger than the industrys average time-series average. Like Frésard and Valta (2016), we exclude tariff cuts that are followed by equivalently large increases in tariffs over the three subsequent years, as well as instances in which the tariff is smaller than 1%.[19]

We then use a difference-in-difference approach to examine the effect of tariff reductions on the measures of expected skewness. We set a $POST$ dummy equal to one if a tariff reduction in the corresponding SIC4 industry occurred during the last three years (excluding the current year) and set it to zero otherwise. Our regression tests have the following form:

$$Skew_{i,t} = \alpha + \beta \times Post_{i,t} + \delta X_{i,t-1} + v_t + \eta_i + \varepsilon_{i,t},$$

where $Skew_{i,t}$ is either the expected idiosyncratic, $IdSkew_{i,t}$, or total, $TotSkew_{i,t}$ skewness measure and X is the set of control variables used in our main tests. Following the literature, we include firm fixed effects (η_i) to absorb time- invariant differences across firms and time fixed effects (v_t) to control for time-varying factors common to all firms and account for potential economy-wide shocks to expected skewness.

Insert Table A1 Here

Results from these regressions are presented in Table A1. Specifications (1)-(3) in that table use expected idiosyncratic skewness as the dependent variable, while specifications (4)-(6) are based on expected total skewness. As the results in table A1 demonstrate, significant tariff reductions have a negative effect on both measures of expected skewness. The effect is stronger for expected total skewness and is also highly statistically significant for that measure. These results provide additional evidence, based on alternative measures of skewness, in support of our main hypothesis of a negative relation between competition and option skew.

[19] We are grateful to Laurent Frésard and Philip Valta for providing tariff data for US manufacturing industries.

References

Aguerrevere, F., 2009, "Real Options, Product Market Competition, and Asset Returns," *Journal of Finance* 64, 957-983.

Amaya, D., P. Christoffersen, K. Jacobs, and A. Vasquez, 2015, "Does Realized Skewness Predict the Cross-Section of Equity Returns?" *Journal of Financial Economics* 118, 135-167.

Back, K., and D. Paulsen, 2009, "Open-Loop Equilibria and Competition in Option Exercise Games," *Review of Financial Studies* 22, 4531-4552.

Bakshi, G., C. Cao, and Z. Chen, 1997, "Empirical Performance of Alternative Option Pricing Models," *Journal of Finance* 52, 2003-2049.

Bakshi, G., N. Kapadia , and D. Madan, 2003, "Stock Return Characteristics, Skew Laws, and the Differential Pricing of Individual Equity Options," *Review of Financial Studies* 16, 101-143.

Bali, T., and S. Murray, 2013, "Does Risk-Neutral Skewness Predict the Cross Section of Equity Option Portfolio Returns?," *Journal of Financial and Quantitative Analyisis* 48, 1145-1171.

Bali, T., J. Hu, and S. Murray, 2017, "Option Implied Volatility, Skewness, and Kurtosis and the Cross-Section of Expected Stock Returns," Working Paper, Georgtown University.

Bekaert, G., and E. Engstrom, 2017, "Asset Return Dynamics under Habits and Bad-Environment Good-Environment Fundamentals," *Journal of Political Economy* 125, 713-760.

Black, F., 1976, "Studies of Stock Price Volatility Changes," In: Proceedings of the 1976 Meetings of the American Statistical Association, Business and Economics Statistics Section, 177-181.

Black, F., and M. Scholes, 1973, "The Pricing of Options and Corporate Liabilities," *Journal of Political Economy* 81, 637-659.

Borodin, A., and P. Salminen, 2002, *Handbook of Brownian Motion*, 2nd edition, Birkhauser Verlag, Basel.

Boyer, B., T. Mitton, and K. Vorkink, 2010, "Expected Idiosyncratic Skewness," *Review of Financial Studies* 23, 169-202.

Bustamante, M.C., and A. Donangelo, 2017, "Product Market Competition and Industry Returns," *Review of Financial Studies* 30, 4216-4266.

Byun S., and D. Kim, 2016, "Gambling Preference and Individual Equity Option Returns," *Journal of Financial Economics* 122, 155-174.

Campello, M., and M. Larrain, 2016, "Enlarging the Contracting Space: Collateral Menus, Access to Credit, and Economic Activity," *Review of Financial Studies* 29, 349-383.

Carlson, M., E. Dockner, A. Fisher, and R. Giammarino, 2014, "Leaders, Followers, and Risk Dynamics in Industry Equilibrium," *Journal of Financial and Quantitative Analyisis* 49, 321-349.

Carlson, M., A. Fisher, and R. Giammarino, 2004, "Corporate Investment and Asset Price Dynamics: Implications for the Cross-Section of Returns," *Journal of Finance* 59, 2577-2603.

Cohen, R., C. Polk, and T. Vuolteenaho, 2003, "The Value Spread," *Journal of Finance* 58, 609-641.

Conrad, J., R. Dittmar, and E. Ghysels, 2013, "Ex Ante Skewness and Expected Stock Returns," *Journal of Finance* 68, 85-124.

Denis, P., and S. Mayhew, 2002, "Risk-Neutral Skewness: Evidence from Stock Options," *Journal of Financial and Quantitative Analysis* 37, 471-493.

DeMiguel, V., Y. Plyakha, R. Uppal, and G. Vilkov, 2013, "Improving Portfolio Selection Using Option-Implied Volatility and Skewness," *Journal of Financial and Quantitative Analyisis* 48, 1813-1845.

Engle, R., and A. Mistry, 2014, "Priced Risk and Asymmetric Volatility in the Cross Section of Skewness," *Journal of Econometrics* 182, 135-144.

Fama, E., and K. French, 1993, "Common Risk Factors in the Returns on Stocks and Bonds," *Journal of Economics* 33, 3-56.

Feenstra, R., J. Romalis, and P. Schott, 2002, "U.S. Imports, Exports, and Tariff Data, 1989-2001," National Bureau of Economic Research Working Paper 9387.

Figlewski, S., and X. Wang, 2000, "Is the "Leverage Effect" a Leverage Effect," Working Paper, New York University.

Frésard, L., 2010, "Financial Strength and Product Market Behavior: The Real Effects of Corporate Cash Holdings, " *Journal of Finance* 65, 1097-1122.

Frésard, L., and P. Valta, 2016, "How Does Corporate Investment Respond to Increased Entry Threat?, " *Review of Corporate Finance Studies* 5, 1-35.

Garlappi, L., 2004, "Risk Premia and Preemption in R&D Ventures," *Journal of Financial and Quantitative Analysis* 39, 843-872.

Geske, R., A. Subrahmanyam, and Y. Zhou, 2016, "Capital Structure Effects on the Prices of Equity Call Options," *Journal of Financial Economics* 121, 231-253.

Giroud, X., and H. Mueller, 2011, "Corporate Governance, Product Market Competition, and Equity Prices," *Journal of Finance* 66, 563-600.

Grenadier, S., 2002, "Option Exercise Games: An Application to the Equilibrium Investment Strategies of Firms," *Review of Financial Studies* 15, 691-721.

Grullon, G., E. Lyandres, and A. Zhdanov, 2012, "Real Options, Volatility, and Stock Returns," *Journal of Finance* 67, 1499-1537.

Gu, L., 2016, "Product Market Competition, R&D Investment, and Stock Returns," *Journal of Financial Economics* 119, 441-455.

Hasanhodzic, J., and A. Lo, 2011, "Black's Leverage Effect Is Not Due to Leverage," Working Paper, MIT.

Heston, S., 1993, "A Closed-Form Solution for Options with Stochastic Volatility with Applications to Bond and Currency Options," *Review of Financial Studies* 6, 327-343.

Hoberg, G., G. Phillips, and M. Prabhala, 2014, "Product Market Threats, Payouts, and Financial Flexibility," *Journal of Finance* 69, 293-332.

Hoberg, G., and G. Phillips, 2010, "Real and Financial Industry Booms and Busts," *Journal of Finance* 65, 45-86.

Hoberg, G., and G. Phillips, 2016, "Text-Based Network Industries and Endogenous Product Differentiation," *Journal of Political Economy* 124, 1423-1465.

Hou, K., 2007, "Industry Information Diffusion and the Lead-Lag Effect in Stock Returns," *Review of Financial Studies* 20, 1113-1138

Hou, K., and D. Robinson, 2006, "Industry Concentration and Average Stock Returns," *Journal of Finance* 61, 1927-1956.

Jeanblanc, M., M. Yor, and M. Chesney, 2009, *Mathematical Methods for Financial Markets*, Springer Verlag, London.

Kim, H., and H. Kung, 2017, "The Asset Redeployability Channel: How Uncertainty Affects Corporate Investment," *Review of Financial Studies* 30, 245-280.

Kelly, B., and H. Jiang, 2014, "Tail Risk and Asset Prices," *Review of Financial Studies* 27, 2841-2871.

Kogan, L., 2004, "Asset Prices and Real Investment," *Journal of Financial Economics* 73, 411-432.

Lambrecht, B., 2001, "The Impact of Debt Financing on Entry and Exit in a Duopoly," *Review of Financial Studies* 14, 765-804.

Lambrecht, B., G. Pawlina, and J. Teixeira, 2016, "Making, Buying, and Concurrent Sourcing: Implications for Operating Leverage and Stock Beta," *Review of Finance* 20, 1013-1043.

Leahy, J., 1993, "Investment in Competitive Equilibrium: The Optimality of Myopic Behavior," *Quarterly Journal of Economics* 108, 1105-1133.

Londono, J., and H. Zhou, 2017, "Variance Risk Premiums and the Forward Premium Puzzle," *Journal of Financial Economics* 124, 415-440.

Miao, J., 2005, "Optimal Capital Structure and Industry Dynamics," *Journal of Finance* 60, 2621-2659.

Moskowitz, T., and M. Grinblatt, 1999, "Do Insdustries Explain Momentum?" *Journal of Finance* 54, 1249-1290.

Pan, J., 2002, "The Jump-Risk Premia Implicit in Options: Evidence from an Integrated Time-Series Study," *Journal of Financial Economics* 63, 3-50.

Pierce, J. and P. Schott, 2016, "The Surprisingly Swift Decline of US Manufacturing Employment," *American Economic Review* 106, 1632-1662.

Pindyck, R., 1988, "Irreversible Investment, Capacity Choice, and the Value of the Firm," *American Economic Review* 78, 969-985.

Rubinstein, M., 1994, "Implied Binomial Trees," *Journal of Finance* 49, 771-818.

Schneider, P., 2015, "Generalized Risk Premia," *Journal of Financial Economics* 116, 487-504.

Toft, K., and B. Prucyk, 1997, "Options on Leveraged Equity: Theory and Empirical Tests," *Journal of Finance* 52, 1151-1180.

Valta, P., 2012, "Competition and the Cost of Debt," *Journal of Financial Economics* 105, 661-682.

Figure 1. Equilibrium output price dynamics with imperfect competition

Figure 1 presents the dynamics of the output price in an industry with n active firms in which reflection takes place instantaneously and with infinitesimal magnitude at $\overline{P}_n$.

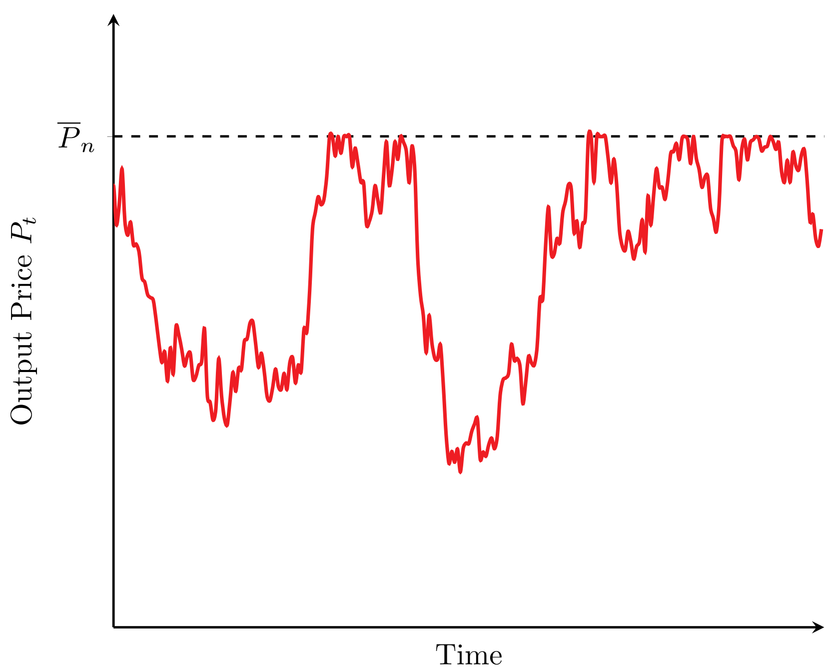

Figure 2. Equilibrium volatility without operating leverage

Figure 2 plots the volatility of stock returns as a function of the level of demand when there is no operating leverage, total output Q does not depend on the number n of firms in the industry, and there are $n \in \{1, 5, 10, 100\}$ firms in the industry. Parameter values are set as follows: $I = 1$, $r = 0.05$, $\sigma = 0.2$, $r - \delta = 0.01$, $\gamma = 1.5$, and $c = 0$. To conserve space, we use the notation Y_n^* for $Y_n^*(Q)$.

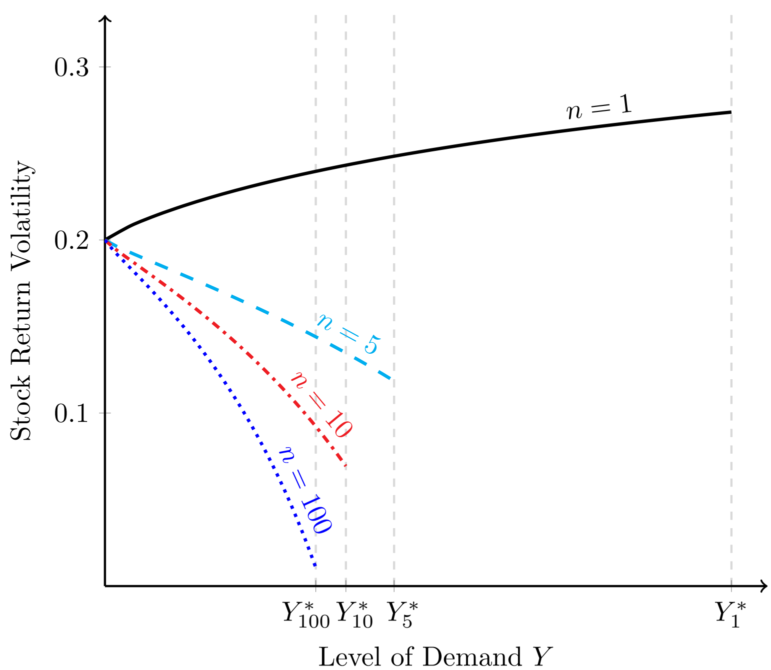

Figure 3. Equilibrium volatility with operating leverage

Figure 3 plots the volatility of stock returns as a function of the level of demand when the firm has operating leverage, total output Q does not depend on the number n of firms in the industry, and there are $n \in \{1, 5, 10, 100\}$ firms in the industry. Parameter values are set as follows: $I = 1$, $r = 0.05$, $\sigma = 0.2$, $r - \delta = 0.01$, $\gamma = 1.5$, and $c = 0.1$. To conserve space, we use the notation Y_n^* for $Y_n^*(Q)$.

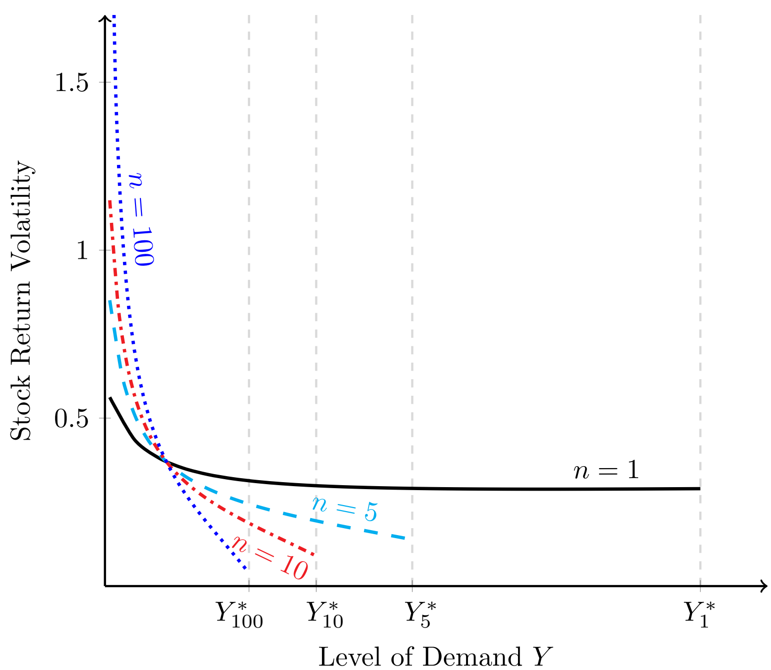

Figure 4. Stock return volatility when output depends on the number of firms

Figure 4 plots the volatility of stock returns as a function of the level of demand when the firm has operating leverage, the level Q_t^n of total output at time t depends on the number n of firms in the industry, and there are $n \in \{1, 5, 10, 100\}$ firms in the industry. Parameter values are set as follows: $I = 1$, $r = 0.05$, $\sigma = 0.2$, $r - \delta = 0.01$, $\gamma = 1.5$, and $c = 0.1$. The investment threshold for new capacity $Y_n^*(Q^n)$ is the same for any number of firms in the market.

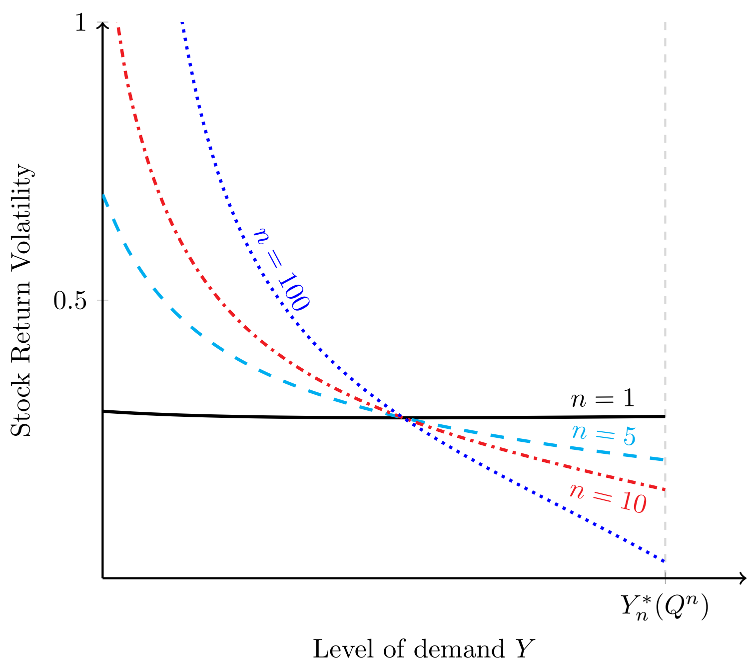

Figure 5. Option skew and product market competition

Figure 5 plots the skewness of log returns under the risk neutral probability measure for $n \in \{1, ..., 100\}$. Parameter values are set as follows: $I = 1$, $r = 0.05$, $\sigma = 0.2$, $r - \delta = 0.01$, $\gamma = 1.5$, and $c = 0$.

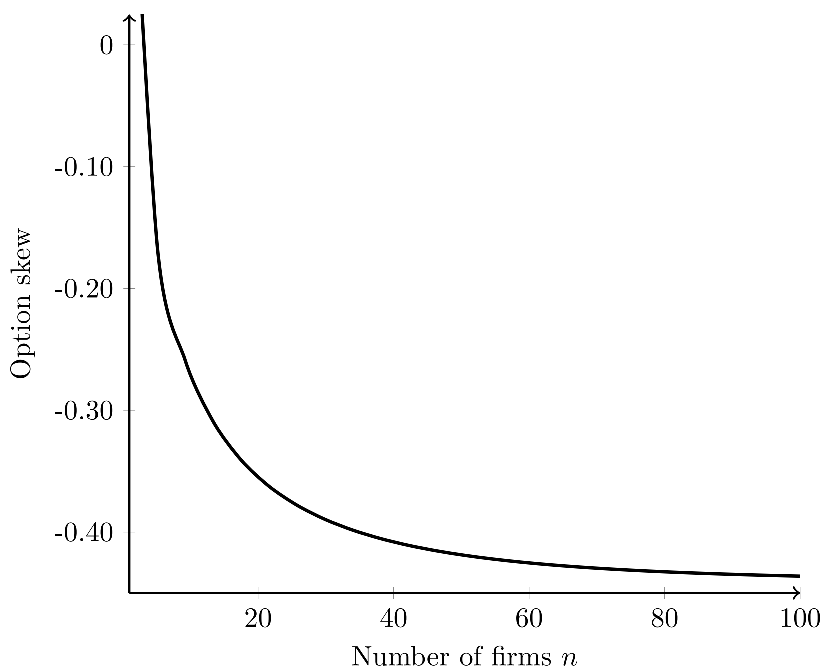

Table 1
Summary Statistics

Table 1 reports summary statistics of the main variables. MFIS is the model-free implied skewness measure. Scaled Option Skew is the difference between Black-Scholes implied volatilities of out-of-the-money calls and out-of-the-money puts, scaled by the average of implied volatilities of at-the-money puts and calls. Fluidity is the fluidity measure of industry competitiveness. TNIC3HHI is the text-based Herfindahl concentration measure. Number of firms SIC3(4)/NAIC3(4) is the number of firms in the 3(4)-digit SIC/NAIC industry. ATM IV is average implied volatility of at-the-money put and call options. Market leverage is the book value of debt divided by the sum of the book value of debt and market value of equity. Market-to-Book is the ratio of market and book values of equity. Size is the market capitalization in million dollars. Cumulative return is past six month cumulative return. Beta is the market beta from 36-month rolling regressions. IdSkew is idiosyncratic skewness of daily returns. MktSkew is market skewness of daily returns.

	Mean	Median	S.D.	Obs
Option Skew Measure				
MFIS, bp	-36.28	-38.01	54.18	244,586
Scaled Option Skew	-0.120	-0.106	0.084	193,715
Competition variables				
Fluidity	7.50	6.77	3.92	211,718
HHI TNIC	0.194	0.134	0.173	222,948
Number of firms SIC3	119.51	36	157.25	244,586
Number of firms SIC4	59.84	22	86.74	244,586
Number of firms NAIC3	217.08	111	224.94	244,586
Number of firms NAIC4	101.99	38	140.00	244,586
Control Variables				
ATM IV	0.445	0.403	0.198	231,439
Market-to-Book	4.91	2.92	6.85	237,796
Market leverage	0.185	0.117	0.208	236,529
Size (Mln $)	9,527	2,230	26,861	237,859
Cumulative return	0.102	0.091	0.374	233,140
Beta	1.303	1.210	0.761	222,312
IdSkew	0.171	0.165	1.04	238,744
MktSkew	-0.050	-0.046	0.658	238,745

Table 2
Model-free Option skew and product market fluidity.

Table 2 reports results from the regressions of option skew on product market fluidity. MFIS is the model-free implied skewness obtained as the third moment of the risk-neutral distribution derived from option prices (multiplied by 100). Fluidity is the fluidity measure of industry competitiveness. See Table 1 for other variable definitions. Standard errors are clustered by firm. Time fixed effects are included.

	(1)	(2)	(3)	(4)	(5)	(6)
Variables	MFIS	MFIS	MFIS	MFIS	MFIS	MFIS
Fluidity	-0.458***	-0.408***	-0.393***	-0.418***	-0.424***	-0.419***
	(0.108)	(0.105)	(0.106)	(0.109)	(0.102)	(0.102)
ATM IV	124.815***	122.954***	125.588***	130.272***	121.842***	122.430***
	(2.012)	(2.049)	(2.111)	(2.292)	(2.300)	(2.302)
Leverage		-14.406***	-16.984***	-17.364***	-13.020***	-12.750***
		(2.190)	(2.194)	(2.228)	(2.157)	(2.160)
Cumret6			-13.038***	-13.318***	-13.499***	-13.791***
			(0.715)	(0.772)	(0.782)	(0.797)
Beta				-1.465***	-1.809***	-1.747***
				(0.410)	(0.389)	(0.388)
Size					-0.360***	-0.362***
					(0.065)	(0.065)
Market-to-Book					-0.567	-0.558
					(0.524)	(0.520)
IdSkew						-3.202***
						(0.099)
MktSkew						-1.837
						(1.246)
Observations	204,954	203,216	199,426	190,890	190,871	190,871
R-squared	0.333	0.335	0.338	0.333	0.351	0.355

Table 3
Alternative competition proxies

Table 3 reports results from the regressions of option skew on alternative competition measures. MFIS is the model-free implied skewness obtained as the third moment of the risk-neutral distribution derived from option prices (multiplied by 100). Panel A reports results for TNIC3HHI. Panel B reports results for the number of firms in the 3/4-digit SIC and NAICS industries (divided by 100). See Table 1 for other variable definitions. Standard errors are clustered by firm. Time fixed effects are included.

Panel A: TNIC3HHI						
	(1)	(2)	(3)	(4)	(5)	(6)
Variables	MFIS	MFIS	MFIS	MFIS	MFIS	MFIS
TNIC3HHI	4.465**	3.710*	3.645*	3.722*	4.488***	4.563***
	(1.972)	(1.942)	(1.957)	(2.012)	(1.708)	(1.708)
ATM IV	123.015***	121.258***	124.019***	128.588***	119.992***	120.630***
	(1.888)	(1.944)	(2.009)	(2.179)	(2.166)	(2.168)
Leverage		-14.394***	-16.916***	-17.323***	-12.921***	-12.617***
		(2.188)	(2.189)	(2.229)	(2.149)	(2.151)
Cumret6			-13.433***	-13.750***	-13.936***	-14.237***
			(0.704)	(0.762)	(0.772)	(0.786)
Beta				-1.393***	-1.714***	-1.649***
				(0.402)	(0.381)	(0.380)
Size					-0.365***	-0.366***
					(0.066)	(0.066)
Market-to-Book					-0.498	-0.494
					(0.448)	(0.444)
IdSkew						-3.274***
						(0.097)
MktSkew						9.509***
						(2.447)
Observations	215,940	214,074	209,917	200,644	200,620	200,620
R-squared	0.331	0.333	0.337	0.332	0.351	0.355

Panel B: Number of firms in SIC and NAICS industries

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Variables	MFIS	MFIS	MFIS	MFIS	MFIS	MFIS	MFIS	MFIS
Number of firms SIC3	-0.604***	-0.887***						
	(0.227)	(0.213)						
Number of firms SIC4			-1.207***	-1.027***				
			(0.450)	(0.393)				
Number of firms NAICS3					-0.294*	-0.449***		
					(0.168)	(0.153)		
Number of firms NAICS4							-0.672**	-0.690***
							(0.300)	(0.266)
ATM IV	125.489***	123.438***	124.862***	122.425***	124.840***	122.616***	124.850***	122.700***
	(1.955)	(2.136)	(1.855)	(2.099)	(1.891)	(2.107)	(1.864)	(2.114)
Leverage		-13.134***		-12.000***		-12.583***		-12.119***
		(2.088)		(2.082)		(2.078)		(2.082)
Cumret6		-14.691***		-14.688***		-14.703***		-14.665***
		(0.747)		(0.747)		(0.747)		(0.747)
Beta		-1.622***		-1.650***		-1.537***		-1.701***
		(0.372)		(0.372)		(0.375)		(0.371)
Size		-0.353***		-0.353***		-0.354***		-0.353***
		(0.060)		(0.060)		(0.060)		(0.060)
Market-to-Book		-0.538		-0.560		-0.573		-0.560
		(0.446)		(0.453)		(0.456)		(0.452)
IdSkew		-3.292***		-3.302***		-3.302***		-3.300***
		(0.093)		(0.093)		(0.093)		(0.093)
MktSkew		16.232***		16.234***		16.396***		16.239***
		(1.201)		(1.202)		(1.202)		(1.200)
Observations	237,026	219,460	237,026	219,460	237,026	219,460	237,026	219,460
R-squared	0.330	0.352	0.330	0.352	0.330	0.352	0.330	0.352

Table 4
The effect of barriers to entry

Table 4 reports results from the regressions of option skew on product market fluidity, tangibility, and an interaction term of tangibility and fluidity. MFIS is the model-free implied skewness obtained as the third moment of the risk-neutral distribution derived from option prices (multiplied by 100). Tang is tangibility defined as the ratio of property plant and equipment and total assets. Tang×Fluid is the interaction term of tangibility and fluidity. See Table 1 for other variable definitions. Standard errors are clustered by firm. Time fixed effects are included.

	(1)	(2)	(3)	(4)	(5)	(6)
Variables	MFIS	MFIS	MFIS	MFIS	MFIS	MFIS
Fluidity	-0.655***	-0.613***	-0.589***	-0.627***	-0.626***	-0.389***
	(0.154)	(0.149)	(0.150)	(0.154)	(0.154)	(0.142)
ATM IV	125.073***	123.487***	126.175***	130.773***	130.791***	118.964***
	(2.076)	(2.088)	(2.149)	(2.328)	(2.328)	(2.327)
Leverage		-14.944***	-17.583***	-17.913***	-17.947***	-18.251***
		(2.293)	(2.295)	(2.324)	(2.323)	(1.995)
Cumret6			-13.117***	-13.405***	-13.380***	-13.687***
			(0.722)	(0.780)	(0.780)	(0.799)
Beta				-1.444***	-1.448***	-1.602***
				(0.409)	(0.408)	(0.389)
Market-to-Book					-0.574	-0.391
					(0.548)	(0.477)
Size						-0.275***
						(0.040)
IdSkew						-3.214***
						(0.099)
MktSkew						-1.783
						(1.250)
Tang	-7.396**	-5.680	-5.022	-5.689	-5.697	-2.823
	(3.630)	(3.672)	(3.695)	(3.755)	(3.754)	(3.310)
Tang×Fluid	0.958**	1.023**	0.991**	1.060***	1.060***	0.665*
	(0.400)	(0.398)	(0.400)	(0.408)	(0.408)	(0.370)
Observations	203,112	201,400	197,655	189,191	189,173	189,173
R-squared	0.333	0.335	0.339	0.334	0.334	0.358

Table 5
Robustness: An alternative measure of option skew and product market fluidity.

Table 5 reports results from the regressions of an alternative measure of option skew on product market fluidity. Scaled Skew is the difference between implied volatilities of out-of-the money calls and out-of-the money puts scaled by the average of implied volatilities of in-the-money calls and in-the-money puts. Fluidity is the fluidity measure of industry competitiveness. See Table 1 for other variable definitions. Standard errors are clustered by firm. Time fixed effects are included.

	(1)	(2)	(3)	(4)	(5)	(6)
Variables	Scaled Skew	Scaled Skew	Scaled Skew	Scaled Skew	Scaled Skew	Scaled Skew
Fluidity	-0.078***	-0.060***	-0.057***	-0.052**	-0.058***	-0.058***
	(0.022)	(0.021)	(0.021)	(0.021)	(0.020)	(0.020)
ATM IV	32.190***	31.900***	32.903***	33.155***	31.533***	31.532***
	(0.794)	(0.813)	(0.841)	(0.935)	(0.882)	(0.882)
Leverage		-2.482***	-2.721***	-2.889***	-2.156***	-2.157***
		(0.517)	(0.516)	(0.524)	(0.516)	(0.516)
Cumret6			-1.537***	-1.492***	-1.481***	-1.480***
			(0.149)	(0.156)	(0.151)	(0.152)
Beta				0.248*	0.181	0.181
				(0.130)	(0.126)	(0.126)
Size					-0.026***	-0.026***
					(0.005)	(0.005)
Market-to-Book					-0.169	-0.170
					(0.142)	(0.142)
IdSkew						0.008
						(0.021)
MktSkew						0.898***
						(0.239)
Observations	172,920	171,725	169,946	165,701	165,693	165,693
R-squared	0.468	0.472	0.475	0.476	0.488	0.488

Table 6
Robustness: sample splits

Table 6 reports results from the regressions of option skew on product market fluidity separately for recessions and expansions and for periods of high (above median) and low (below median) VIX. MFIS is the model-free implied skewness obtained as the third moment of the risk-neutral distribution derived from option prices (multiplied by 100). Fluidity is the fluidity measure of industry competitiveness. See Table 1 for other variable definitions. Standard errors are clustered by firm. Time fixed effects are included.

	Recessions		Expansions		Low VIX		High VIX	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Variables	MFIS	MFIS	MFIS	MFIS	MFIS	MFIS	MFIS	MFIS
Fluidity	0.034	0.018	-0.559***	-0.532***	-0.508***	-0.471***	-0.503***	-0.459***
	(0.154)	(0.155)	(0.112)	(0.106)	(0.126)	(0.121)	(0.106)	(0.102)
ATM IV	77.152***	69.642***	135.337***	135.874***	161.923***	160.233***	104.474***	101.738***
	(2.575)	(3.074)	(2.214)	(2.623)	(3.369)	(4.027)	(1.847)	(2.205)
Leverage		-17.518***		-9.709***		-15.738***		-8.952***
		(2.712)		(2.266)		(2.739)		(2.064)
Cumret6		-5.188***		-16.670***		-18.862***		-12.189***
		(1.063)		(1.025)		(0.927)		(1.014)
Beta		1.157		-2.096***		-1.819***		-1.481***
		(0.745)		(0.410)		(0.486)		(0.473)
Size		-0.303***		-0.365***		-0.327***		-0.374***
		(0.051)		(0.067)		(0.064)		(0.063)
Market-to-Book		-2.649***		-0.450		-0.183		-1.553***
		(0.681)		(0.494)		(0.514)		(0.426)
IdSkew		-3.278***		-3.196***		-3.041***		-3.362***
		(0.253)		(0.104)		(0.122)		(0.149)
MktSkew		32.995***		-2.406*		-3.497***		-10.186***
		(1.701)		(1.256)		(0.303)		(2.360)
Observations	28,028	25,930	176,926	164,941	98,641	92,841	106,313	98,030
R-squared	0.265	0.288	0.336	0.360	0.281	0.315	0.322	0.339

Table 7
Robustness: annual frequency

Table 7 reports results from the regressions of option skew on product market fluidity at the annual frequency. MFIS is the model-free implied skewness obtained as the third moment of the risk-neutral distribution derived from option prices (multiplied by 100). Fluidity is the fluidity measure of industry competitiveness. See Table 1 for other variable definitions. Standard errors are clustered by firm. Time fixed effects are included.

	(1)	(2)	(3)	(4)	(5)	(6)
Variables	MFIS	MFIS	MFIS	MFIS	MFIS	MFIS
Fluidity	-0.439***	-0.394***	-0.404***	-0.406***	-0.394***	-0.387***
	(0.102)	(0.100)	(0.101)	(0.105)	(0.099)	(0.098)
ATM IV	109.912***	107.365***	112.500***	115.231***	107.011***	108.063***
	(1.909)	(1.952)	(2.104)	(2.424)	(2.480)	(2.475)
Leverage		-12.680***	-15.704***	-16.352***	-12.606***	-12.220***
		(1.914)	(1.942)	(1.993)	(1.957)	(1.955)
Cumret6			-17.429***	-18.205***	-18.136***	-17.457***
			(1.135)	(1.237)	(1.241)	(1.231)
Beta				-0.376	-0.569	-0.484
				(0.427)	(0.409)	(0.409)
Size					-0.410***	-0.412***
					(0.074)	(0.075)
Market-to-Book					-0.718	-0.648
					(0.474)	(0.467)
IdSkew						-5.777***
						(0.548)
MktSkew						3.646***
						(1.333)
Observations	26,286	26,135	25,213	23,998	23,997	23,997
R-squared	0.392	0.394	0.402	0.393	0.421	0.426

Table 8
The effect of granting the PNTR status to China on the option skew

Table 8 reports results from the regressions of option skew on the Post NTR dummy. MFIS is the model-free implied skewness obtained as the third moment of the risk-neutral distribution derived from option prices (multiplied by 100). Post NTR dummy is set to 1 for dates after October 2000 (the date when congress granted PNTR status to China) for manufacturing industries and set to zero otherwise. See Table 1 for other variable definitions. Standard errors are clustered by firm.

	(1)	(2)	(3)	(4)	(5)	(6)
Variables	MFIS	MFIS	MFIS	MFIS	MFIS	MFIS
Tardummy	-5.671***	-5.418***	-7.019***	-11.306***	-11.769***	-12.731***
	(0.946)	(0.940)	(0.997)	(0.999)	(1.338)	(1.364)
ATM IV	146.004***	147.043***	146.486***	136.355***	136.116***	134.783***
	(3.047)	(3.003)	(3.604)	(3.562)	(3.531)	(3.787)
Leverage		-40.204***	-37.078***		-27.977***	-24.710***
		(5.401)	(5.766)		(5.715)	(5.583)
Cumret6		-9.377***	-10.072***		-8.098***	-8.637***
		(0.738)	(0.797)		(0.747)	(0.803)
Beta			0.444			1.611
			(1.010)			(0.994)
Size			-0.070			-0.025
			(0.108)			(0.033)
Market-to-Book			0.000			0.000
			(0.000)			(0.000)
Idskew			-4.977***			-4.943***
			(0.217)			(0.216)
Mktskew			2.154***			2.716***
			(0.393)			(0.382)
Observations	63,849	61,447	57,548	63,849	61,447	57,551
R-squared	0.322	0.323	0.326	0.328	0.331	0.335
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects	No	No	No	Yes	Yes	Yes

Table 9
The effect of the tariff gap on the option skew.

Table 9 reports results from the regressions of option skew on the interaction of the Post NTR dummy and the NTR Gap. MFIS is the model-free implied skewness obtained as the third moment of the risk-neutral distribution derived from option prices (multiplied by 100). Post NTR dummy is set to 1 for dates after October 2000 (the date when congress granted PNTR status to China.) NTRGap is the gap between non-NTR and NTR tariffs. PostNTR×NTRGap is the interaction term of Post NTR dummy and NTRGap. See Table 1 for other variable definitions. Standard errors are clustered by firm.

	(1)	(2)	(3)	(4)	(5)	(6)
Variables	MFIS	MFIS	MFIS	MFIS	MFIS	MFIS
PostNTR×NTRGap	-11.379**	-18.449***	-24.962***	-38.318***	-39.044***	-44.556***
	(4.666)	(4.525)	(4.522)	(5.519)	(5.449)	(5.519)
ATM IV	136.627***	131.128***	138.478***	130.597***	126.141***	123.639***
	(4.822)	(4.863)	(5.772)	(6.037)	(5.269)	(6.737)
Leverage		-29.673***	-26.511**		-23.441**	-20.250*
		(9.883)	(10.612)		(9.739)	(10.439)
Cumret6		-12.085***	-12.245***		-10.783***	-11.002***
		(1.298)	(1.432)		(1.352)	(1.465)
Beta			4.223**			5.221***
			(1.753)			(1.756)
Size			-0.066*			-0.069*
			(0.040)			(0.042)
Market-to-Book			-0.000			-0.000
			(0.000)			(0.000)
IdSkew			-4.829***			-4.756***
			(0.394)			(0.398)
MktSkew			2.544***			2.766***
			(0.623)			(0.638)
Observations	34,583	33,568	31,663	34,583	33,568	31,825
R-squared	0.246	0.250	0.256	0.253	0.255	0.260
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects	No	No	No	Yes	Yes	Yes

Table A1
The effect of the tariff reductions on expected skewness

Table A1 reports results from the regressions of option skew on the *Post* dummy. PIDSKEW is the predicted idiosyncratic skewness. PTOTSKEW is the predicted total skewness. *Post* dummy is set to one in the three year period following a tariff reduction in the corresponding 4-digit SIC industry. See Table 1 for other variable definitions. Firm and time fixed effects are included. Standard errors are clustered by firm.

	(1)	(2)	(3)	(4)	(5)	(6)
Variables	PIDSKEW	PIDSKEW	PIDSKEW	PTOTSKEW	PTOTSKEW	PTOTSKEW
Post	-0.003*	-0.004*	-0.004*	-0.005***	-0.005***	-0.005***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Beta		0.006***	0.006***		0.007***	0.007***
		(0.001)	(0.001)		(0.001)	(0.001)
Size		-0.008***	-0.005***		-0.011***	-0.008***
		(0.001)	(0.001)		(0.001)	(0.001)
Leverage			0.030***			0.034***
			(0.005)			(0.005)
Market-to-Book			-0.000			-0.000
			(0.000)			(0.000)
Observations	300,340	284,557	283,586	300,340	284,557	283,586
R-squared	0.182	0.183	0.184	0.176	0.178	0.179