Capital Structure under Foreign Competition

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Abstract

I investigate how foreign competition influences domestic firm leverage. Empirical work connecting the two is sparse and inconsistent. It is surprising that although the results for how foreign competition influences profitability are unanimously negative, the results for leverage can be positive or negative. To better understand the discrepancy, I build a dynamic capital structure model in industry equilibrium with a trade-off theory leverage decision and foreign competition. Particularly, the model differentiates among two channels underlying foreign competition, increases in foreign competitiveness and reductions in trade policy uncertainty. The first channel implies decreased domestic leverage, so cannot alone match the empirics. However, the second channel can, implying both decreased profitability and increased leverage. Finally, using a new empirical strategy, I find support for the model's predictions on how both channels influence leverage.

With an increasingly globalized world and falling trade barriers, domestic firms are now exposed to import competition from foreign firms. There has been a wide array of domestic firm reactions, ranging from labor to innovation to investment decisions. On the corporate finance end, there is reason to believe that capital structure should react too. This is because optimal capital structure decisions are intertwined with product market competition (Miao 2005, Fresard 2010) and intensified foreign competition is empirically reflected in the cost of capital (Barrot et al (2016) Valta (2012)).

Capital structure reactions to foreign competition are not only important from a corporate finance perspective, but also from a macro perspective, since levered agents are more exposed to additional shocks. A link has already been established between foreign competition and household leverage. Empirical evidence suggests that foreign competition increased U.S. household leverage just prior to the 2008 mortgage crisis (Barrot et al 2017). In a similar way, firm leverage reactions could also affect stability.

This question has been largely unexplored. Moreover, the work that does exist disagrees. Although prior work consistently concludes that foreign competition has negative effects on firm profitability, evidence tying foreign competition to leverage has found positive and negative results. Baggs and Brander (2006) find a positive effect on leverage

using tariff decreases following a NAFTA free trade agreement as the competition measure. On the contrary, Xu (2012) finds a negative effect using the foreign share of total industry production in US manufacturing industries as the competition measure. These conflicting results are surprising. As little theoretical work exists on the connection between foreign competition and capital structure, it is difficult to conceptualize the underlying forces at play. I bridge this gap by building and empirically supporting a model of the leverage decision under foreign competition.

To start, I build a model connecting foreign competition to leverage. I use a real option model of industry equilibrium, where foreign and domestic firms decide entry, exit, and leverage in a trade-off theory context. I use the model to examine two channels underlying foreign competition in how they impact leverage. The first is foreign competitiveness, stemming from findings that falling trade barriers and rising foreign productivity increase import competition. The second is trade policy uncertainty. The motivation for this channel stems from findings that trade policy uncertainty is important for exporter behavior and from its relevance to today's political climate. Moreover, a key difference in the two disagreeing papers is the presence of a trade policy event. Since trade policy uncertainty is important for exporting firms, I conjecture that it is also important for import competing firms and has the capacity to reconcile the empirical results on import competition and leverage.

For the first channel, parameters representing foreign competitiveness include entry costs, operating costs, productivity, and cash flow growth rate. All of these have the same qualitative implications. With an increase in foreign competitiveness, the industry price decreases and the domestic share of the industry decreases. With decreased profitability prospects, domestic exit probabilities increase, raising the expected bankruptcy costs of debt relative to the tax benefits of debt. At the firm level, optimal leverage decreases. The model also makes predictions for the industry level. In addition to the profitability effect, at the industry level there is a selection effect. The domestic firms with low revenue shock realizations exit the industry and are replaced with firms with high ones, leaving the average increased. The selection effect alone would increase average industry leverage. However, the model predicts that the profitability effect dominates the selection effect, resulting in decreased industry level leverage.

The second channel is trade policy uncertainty. Motivated by literature on trade policy uncertainty, I introduce trade policy as an arrival process. Upon derivation, this is equivalent differentiating the volatility parameter underlying firm value calculations and decisions from the one defining the realized cash flow variation and the stationary distribution of firms. The difference between these parameters is where trade policy uncertainty is represented in the model. Accordingly, I vary this difference to conduct comparative statics.

The model identifies two competing forces for the effect of the trade policy uncertainty

on leverage. First, there is a volatility effect. Volatility increases the expected probability of default, raising the expected bankruptcy costs of debt relative to the tax benefits of debt. As such, increased volatility decreases the optimal level of debt compared to equity. Second, there is a price feedback effect. The model reveals that uncertainty in future competition deters new firms from entering, propping up prices and leaving domestic firms more profitable with lower exit probability. This price feedback effect lowers the expected bankruptcy costs of debt relative to the tax benefits of debt, leading to a higher optimal level of debt compared to equity. The model predicts that the first effect outweighs the second, resulting in lower optimal leverage.

The model offers uncertainty reduction as a trade-off theory consistent mechanism underlying empirical disagreement. On the surface, it is puzzling that two papers with similar empirical settings would agree on how foreign competition affects profitability, yet disagree on leverage. However, the paper finding a positive effect on leverage relies on a trade policy event in its identification strategy and the other does not. The model predicts that both uncertainty reduction and increased competition should have negative profit effects. However, it predicts that uncertainty reduction should have a positive leverage effect and increased foreign competitiveness a negative leverage effect. The model results suggest that trade policy uncertainty can reconcile the literature's disagreement in a trade-off theory consistent way.

I document new empirical results that suggest a distinction between how capital structure reacts to increases in foreign competitiveness versus trade policy uncertainty. I blend the approaches of the two aforementioned papers using the case of Chinese competition in the US. The surge in Chinese manufacturing competition for U.S. firms over the past few decades is a particularly stark and well-studied example of foreign competition, with documented effects ranging from labor to innovation to finance. I use shipping costs as a measure of trade exposure. The logic is that Chinese firms in low shipping cost industries will find it easier to export to the U.S. and Chinese exports will be more sensitive to productivity shocks (Barrot et al 2016, 2017). As a result, domestic firms in low shipping cost industries will be more exposed to foreign competition.

At the same time, China's accession to the WTO was an important piece of trade policy that exacerbated competition for US manufacturing firms. Political history indicates that the time before WTO accession represents presence of uncertainty in foreign competition. Moreover, estimates of trade policy uncertainty reveal decreases following China's WTO accession (Handley and Limao 2017). Estimates of foreign export entry and import competition similarly reveal large increases following China's WTO accession (Handley and Limao 2017, Crowley et al 2018).

Using a difference in difference approach, I empirically compare how the relationship between trade exposure and leverage changed with trade shocks surrounding the WTO event. Analogous to the model, I examine two different shocks to import competition: for-

eign competitiveness and trade policy uncertainty. The difference between the base and WTO uncertainty period represents a positive trade policy uncertainty shock. The difference between the WTO uncertainty period and post-WTO period represents the combined effect of a negative trade policy uncertainty shock and positive foreign competitiveness shock.

In the cross-sectional difference, I find a negative association between trade exposure and leverage. In the period differences I find that this relationship intensifies with increases in uncertainty and foreign competitiveness and weakens with uncertainty reductions. This suggests that foreign competitiveness and uncertainty negatively influence leverage, while uncertainty reduction positively influences leverage. Accordingly, these results support the model's predictions and the proposition that trade policy uncertainty can reconcile the literature's empirical disagreement.

The rest of the paper is laid out as follows. Section I provides a literature review. Section II develops the model. Section III conducts comparative statics and interprets results. Section IV presents the data and empirical analysis. Finally, Section V concludes.

I. Literature

This paper relates the three main strands of literature: 1. Domestic market reactions to import competition 2. Capital structure 3. Models of industry dynamics with stationary equilibrium.

The import competition literature analyzes a wide range of domestic market effects. Most prominently is the effect on labor markets. Numerous studies examine the impact on employment and wages (Autor, Dorn, and Hansen (2013) Revenga (1992) Acemoglu et al (2016)). Autor and Dorn (2013) additionally look at changes in job skill demands. A second area involves how import competition affects productivity and innovation. A central question is to what extent productivity increases are due to within firm improvements versus resource reallocation across firms towards the more efficient ones (Scherer and Huh (1992) MacDonald (1994) Bernard, Jensen, Schott (2006) Bloom, Draca, Van Reenen (2015)).

Work on the financial effects of import competition is more sparse. On the asset pricing end, Barrot et al (2016) find a risk premium on equity prices associated with globalization, centered around import competition induced displacement risk. Along similar lines, Valta (2012) finds that credit spreads increase in response to tariff reductions. On the corporate finance end, evidence supports that firm investment responds the import competition, as Fresard and Valta (2016) find that firms reduce investment in response to import tariff reductions. Barrot et al (2017) study household financial decisions and find a positive effect of import competition on household debt growth.

Studies specifically connecting import competition with capital structure are empir-

ical and contradictory. There are two main papers on this topic with opposite conclusions. Baggs and Brander (2006) use Canadian trade tariff reductions to study the effect on leverage. They find that import tariff reductions decrease profitability and increase leverage, particularly for import competing firms. Xu (2012) uses the import share of total industry production to measure import competition and studies its effect on leverage. She finds that import competition decreases leverage via decreased profitability. Our empirical work is most similar to Xu (2012), with key differences in import competition measure.

The second relevant line of literature studies capital structure. The foundational work lies in Modigliani and Miller (1957), which show conditions under which capital structure is irrelevant for firm value. The trade-off theory departs from these conditions by including tax benefits to debt and the option to declare bankruptcy. In this model, the possibility of bankruptcy creates a tension between the tax benefits of debt and the bankruptcy costs in choosing value maximizing split of debt and equity financing. Firms balance the two effects to find optimal capital structure. In this paper, I consider leverage implications within the context of the trade-off model. Miao (2012) embeds industry competition within the trade-off model in order to explain a set of puzzling facts. This setting differs in that there are two types of firms, where one type becomes more competitive, and the outcome of interest is the impact on the second.

The third area involves models of industry equilibrium with entry and exit. Hopenhayn (1992a, 1992b) and Hopenhayn and Rogerson (1993) developed a discrete time framework to analyze industry entry and exit, where the equilibrium notion involves a stationary distribution of firms. Melitz (2003) looks at foreign and domestic selection into exporting with firm level heterogeneity in productivity, but without endogenous exit or leverage. Models that incorporate trade policy uncertainty in industry equilibrium use similar methods, such as Handley and Limao (2017). I build off of Dixit and Pindyck (1994, chapter 8), which constructs a continuous time model with firm specific uncertainty.

II. Model

Consider an industry of risk-neutral firms in continuous time, where potential firms may enter and existing firms may exit. The industry is perfectly competitive, so firms are price takers. In addition, each firm faces exogenous idiosyncratic revenue uncertainty. The objective is to characterize the stationary equilibrium when two types of potential firms, foreign and domestic, may participate in the market.

A. Demand

Industry demand is a decreasing function of price. Accordingly, the inverse demand function is a decreasing function of quantity. I assume isoelastic demand, resulting in the following form for the inverse demand function:

$$P = Q^{-\epsilon} \tag{1}$$

P stands for industry price, Q for industry quantity, and $1/\epsilon$ for the price elasticity of demand.

B. Firms

In the industry, a new generation of potential firms with mass N is born at each instant. Each firm receives an initial idiosyncratic shock, X, drawn from a probability distribution with density $g(X)$. For simplicity, I assume uniform distribution over $[0, \hat{X}]$. Upon receiving the initial draw, firms choose their debt coupon and whether or not to enter. Potential firms that do not enter die off in the next instant, while firms that decide to enter pay entry cost I begin production. Active firms produce 1 unit of output flow and continuously adjust their debt coupon until they face exogenous death at rate λ or choose to exit.

1B. Profit Function

I follow the basic Dixit and Pindyck (1994) framework to derive the profit function. The highlights of this framework involve two key assumptions. Since including firm decisions on both the extensive (i.e. entry/exit) and intensive (i.e. quantity produced) margins complicates the analysis, these simplifying assumptions allow focus on entry/exit. Later work could extend the model to incorporate the intensive margin.

First, I assume that active firms must produce 1 unit of output flow. For micro-foundations, as explained in Dixit and Pindyck (1994), I can formulate a primitive production function that corresponds with this assumption. Allowing one type of input, v, which takes values 0 or 1, the production function is defined in the following way:

$$h(v) = \begin{cases} 0 & v = 0 \\ 1 & v = 1 \end{cases} \tag{2}$$

This means that if firms enter, they continuously use 1 unit of input to produce 1 unit of output flow. Additionally, I require firms to exit and pay exit cost in order to produce 0, which prohibits firms from temporarily suspending production without cost. I next define the cost function in a similar way:

$$C(v) = \begin{cases} 0 & v = 0 \\ C & v = 1 \end{cases} \tag{3}$$

In other words, active firms continuously pay cost C for 1 unit of input flow.

The second assumption introduces firm-specific uncertainty through an exogenous revenue shock, X. This shock enters as a multiple of the industry price, resulting in the below firm-specific revenue function. Note also that this formulation is equivalent to interpreting X as firm-specific demand uncertainty.

$$R = X \cdot P \cdot h(v) \tag{4}$$

The idiosyncratic revenue shock follows a geometric Brownian motion, $dX = \alpha X dt + \sigma X dW + X dq$, where α is the drift, σ the diffusion, and dq the Poisson death process with arrival rate λ such that:

$$dX = \begin{cases} 0 & \text{with probability } (1 - \lambda dt) \\ -X & \text{with probability } \lambda dt \end{cases}$$

Now, given the revenue expression, cost function, and price expression, I derive the after tax firm profit flow:

$$\pi(X, Q) = (1 - \tau) \cdot (X \cdot P \cdot h(v) - C(v)) = (1 - \tau) \cdot (XQ^{-\epsilon} - C) \tag{5}$$

Firms choose entry and exit to maximize firm value, the sum of expected discounted profits over $\{t\}_0^\infty$. Since there is a competitive industry, firms treat industry quantity as a given constant. This leaves changes in profit dependent on the idiosyncratic revenue shock, X. Accordingly, firms choose threshold X levels at which to take an entry/exit action. For the potential firm, this action is to enter, and for the active firm, to exit. To specify the thresholds, I follow standard dynamic programming methods for optimal stopping problems. Essentially, I express firm value as a function of X and form conditions for optimal entry/exit to define the action thresholds.

2B. Inactive Firm Value

The value of the inactive firm is the solution to the below Bellman equation:

$$rV_0(X, Q)dt = E[dV_0(X, Q)] \tag{6}$$

$$V_0(X, Q) = K \cdot (XQ^{-\epsilon})^{\beta_1} \tag{7}$$

K is a constant to be determined, while β_1 is the positive root of the fundamental

quadratic equation. Intuitively, Equation (7) expresses the value of the potential firm, which consists only of the option to enter. We can think of this as the opportunity cost of entering the market, or in other words the outside value of the initial idiosyncratic revenue draw.

3B. Unlevered Equity Value

First, consider the value of unlevered equity. The Bellman equation is given by,

$$rU(X,Q)dt = \pi(X,Q)dt + E[dU(X,Q)] \tag{8}$$

Expanding the expectation in these equations and simplifying leads to a differential equation:

$$(r+\lambda)\cdot U = \frac{1}{2}\sigma^2 U_{XX}X^2 + \mu U_X X + \pi \tag{9}$$

Below are the boundary conditions:

$$U(X_L,Q) = 0 \tag{10}$$

$$U_X(X_L,Q) = 0 \tag{11}$$

Once the idiosyncratic shock, X, reaches low enough level, X_L, such that the equity value is 0, the firm exits the industry. In other words, at X_L the firm reaches the point of willingness to exercise its option to exit, which means paying the exit cost and giving up production and the option to exit in favor of stopping production.

The solution is of the following form:

$$U(X,Q) = A_1\cdot(XQ^{-\epsilon})^{\beta_2} + \frac{(1-\tau)\cdot XQ^{-\epsilon}}{\delta+\lambda} - \frac{(1-\tau)\cdot C}{r+\lambda} \tag{12}$$

A_1 is a constant to be determined, while β_2 is the negative root of the fundamental quadratic equation below:

$$F(\beta) = \frac{1}{2}\sigma^2\beta(\beta-1) + \alpha\beta - (r+\lambda) = 0 \tag{13}$$

Intuitively, equation (12) expresses the value of the active firm as the sum of the value of the option to exit (first term) and the value of actual production (next two terms).

4B. Debt Value

First consider a security that pays 1 at the default boundary. Below is the pde:

$$(r+\lambda)\cdot q = \frac{1}{2}\sigma^2 q_{XX}X^2 + \mu q_x X \tag{14}$$

Below is the boundary, where X_L denotes the cash flow level at the time of default, or in other words, the exit threshold. X_L will be determined later, in equilibrium.:

$$q(X_D) = 1 \tag{15}$$

Below is the solution:

$$q(X) = \left(\frac{X}{X_D}\right)^{\beta_2} \tag{16}$$

Below is the debt pde:

$$(r+\lambda)\cdot D = \frac{1}{2}\sigma^2 D_{XX}X^2 + \mu D_X X + b \tag{17}$$

Below is the debt boundary:

$$D(X_D) = (1-\alpha)\cdot U(X_D, Q) \tag{18}$$

Below is the solution for the value of debt:

$$D(X,Q,b) = \frac{b}{r+\lambda}\cdot(1-q(X)) + (1-\alpha)\cdot U(X_D,Q)\cdot q(X) \tag{19}$$

This follows the standard intuition that debt holders receive the coupon payment while the firm is active and get a portion of the firm asset value in the case of bankruptcy.

5B. Levered Equity Value

Next, consider the value of levered equity:

I modify the after tax profit function to include the coupon payment, denoted as b:

$$\pi(X,Q,b) = (1-\tau)\cdot(X\cdot P\cdot h(v) - C(v) - b) = (1-\tau)\cdot(XQ^{-\epsilon} - C - b) \tag{20}$$

The Bellman equation is given by:

$$rL(X,Q,b)dt = \pi(X,Q,b)dt + E[dL(X,Q,b)] \tag{21}$$

After calculating the expectation, below is the resulting pde:

$$(r+\lambda)\cdot L_X = \frac{1}{2}\sigma^2 L_{XX}X^2 + \mu L_{XX}X + \pi \tag{22}$$

Below are the boundary conditions:

$$L(X_D, Q, b) = 0 \tag{23}$$

$$L_X(X_D, Q, b) = 0 \tag{24}$$

Once the idiosyncratic shock, X, reaches low enough level, X_D, such that the equity value is 0, the firm defaults on outstanding debt and exits the industry.

The solution for levered equity value is of the following form:

$$L(X, Q, b) = A_2 \cdot (XQ^{-\epsilon})^{\beta_2} + \frac{(1-\tau) \cdot XQ^{-\epsilon}}{\delta + \lambda} - \frac{(1-\tau) \cdot (C+b)}{r+\lambda} \tag{25}$$

Similar to the value of unlevered equity, A_2, is a constant to be determined and β_2 is the negative root of the fundamental quadratic.

Using the boundary conditions, I solve for the default threshold below:

$$X_D = \frac{\beta_2}{\beta_2 - 1} \cdot \frac{(b+C) \cdot (\delta + \lambda)}{r+\lambda} \cdot Q^{\epsilon} \tag{26}$$

Now L is defined by plugging X_D back in.

6B. Levered Firm Value

Firms choose the coupon value that maximizes the sum of levered equity and debt:

$$V_L(Q, X, b) = \max_b (L + D) \tag{27}$$

The following equation defines the coupon value. Derivation details are in Appendix 3.

$$\tau S^{-1}(b+C)^{\beta_2+1} = b(-\tau\beta_2 + \tau - \alpha(1-\tau)\beta_2) + \tau C \tag{28}$$

S is defined below:

$$S = \left(\frac{X}{\frac{\beta_2}{\beta_2 - 1} \cdot \frac{\cdot(\delta+\lambda)}{r+\lambda} \cdot Q^{\epsilon}} \right)^{\beta_2} \tag{29}$$

If $C = 0$ then:
$b = (1 - \beta_2 - \frac{1-\tau}{\tau}\alpha\beta_2)^{\frac{1}{\beta_2}} \left(\frac{XQ^{-\epsilon}}{\frac{\beta_2}{\beta_2 - 1} \cdot \frac{(\delta+\lambda)}{r+\lambda}} \right)$

This makes sense intuitively, b increases with X and τ and decreases with Q and ϵ. (Remember that β_2 is negative.)

C. Entry conditions

Next, I specify conditions for optimal entry, which connect the value of the inactive firm to the value of the levered active firm:

$$V_0(X_H, Q) = V_L(X_H, Q, b) - I \tag{30}$$

$$V_L'(X_H, Q, b) = V_0'(X_H, Q) \tag{31}$$

Equation (30) is the value matching condition, while (31) is the smooth pasting condition. X_H is the entry threshold. Intuitively, when X has reached high enough level, X_H, the firm is willing to exercise its option to enter, which means paying the entry cost and giving up the opportunity cost in favor of production and the option to exit. The unknown variables are now X_H, K, and Q. (but Q will be determined in industry equilibrium). So next I will solve for X_H and K as functions of the rest of the variables. Derivation details are in Appendix 4.

$$K = (X_H Q^{-\epsilon})^{-\beta_1}[V_L(X_H, Q, b) - I] \tag{32}$$

The equation defining X_H is as follows:

$$\beta_1[V_L(X_H,Q,b)-I] = (1-\tau)[\frac{X_H Q^{-\epsilon}}{\delta+\lambda}+\beta_2[\frac{C}{r+\lambda}-\frac{X_L Q^{-\epsilon}}{\delta+\lambda}]\left(\frac{X_H^{\beta_2}}{X_L^{\beta_2}}\right)]-\beta_2\left(\frac{X_H^{\beta_2}}{X_D^{\beta_2}}\right)(\frac{\tau\cdot b}{r+\lambda}+\alpha\cdot U(X_D,Q))+X_H\cdot\frac{\tau}{r+\lambda}(\tag{33}$$

where

$$\frac{db}{dX} = \frac{\beta_2 X^{-\beta_2-1}(b+C)^{\beta_2} R}{b^{-1} + R\cdot X^{-\beta_2}(b+C)^{\beta_2}[\beta_2(b+C)^{-1} - b^{-1}]} \tag{34}$$

$$R = \left(\frac{\beta_2}{\beta_2 - 1}\cdot\frac{\delta+\lambda}{r+\lambda}\cdot Q^{\epsilon}\right)^{\beta_2} \tag{35}$$

D. Equilibrium: Domestic firms

1D. Stationary Distribution

I now find the stationary distribution of active firms that results in equilibrium. Since it is easier to calculate the stationary distribution of a simple Brownian motion, I work in terms of $x = ln(X)$. To start, I use the binomial approximation to a simple Brownian

motion. I use step size of $dh = \sigma\sqrt{dt}$ and specify the fraction of firms that move up by $p = \frac{1}{2}[1 + \frac{\alpha - .5\sigma^2}{\sigma}\sqrt{dt}]$ and down by $q = \frac{1}{2}[1 - \frac{\alpha - .5\sigma^2}{\sigma}\sqrt{dt}]$. In the stationary distribution, $\phi(x)$, the number of firms at each x remains constant, requiring that the number arriving equals the number leaving. I provide a diagram to illustrate the arrival and departure flow associated with x:

$$\text{arrivals} = \begin{cases} x + dh & p(1 - \lambda dt) \cdot \phi(x - dh)dh \\ \text{industry entry} & \Rightarrow \quad Ng(exp(x))dh \\ x - dh & q(1 - \lambda dt) \cdot \phi(x + dh)dh \end{cases}$$

This diagram shows the source of arrival in the left column and the number of firms arriving in the right column. The top and bottom rows denote the segments above and below x, respectively, while the middle row denotes the number of new firms entering the industry.

$$\text{departures} = \begin{cases} x + dh & q(1 - \lambda dt) \cdot \phi(x)dh \\ \text{industry exit} & \Leftarrow \quad \lambda dt \cdot \phi(x)dh \\ x - dh & p(1 - \lambda dt) \cdot \phi(x)dh \end{cases}$$

Similarly, this diagram shows the destination of departure in the left column and the number of firms departing in the right column. The top and bottom rows denote the segments above and below x, respectively, while the middle row denotes the number of firms that face exogenous death.

Setting the sum of arriving firms equal to sum of departing firms results in the following condition:

$$\phi(x)dh = Ndt \cdot g(x)dh + p(1 - \lambda dt)\phi(x - dh)dh + q(1 - \lambda dt)\phi(x + dh)dh \tag{36}$$

Upon simplification, this gives differential equation with general solution of the following form:

$$\phi(x) = C_1 exp[\gamma_1 x] + C_2 exp[\gamma_2 x] + \phi_0(x) \tag{37}$$

The first two terms denote the solution to the homogeneous part of the differential equation, with C_1 and C_2 as constants to be determined, and γ_1 and γ_2 as the positive and negative roots of the fundamental quadratic below. The last term of (37) denotes the particular solution to the full differential equation.

$$F(\gamma) = \frac{1}{2}\sigma^2\gamma^2 - (\alpha - .5\sigma^2)\gamma - \lambda = 0$$

The derivation is not yet complete, as I need to make one further adjustment to the stationary distribution. Note that active firms exist in $[x_L, \infty)$, while new firms only enter

in $[x_H, \hat{x}]$. This means that the second line of the arrivals diagram only applies in the $[x_H, \hat{x}]$ region of the distribution, and, accordingly, equations (36) and (37) only apply for $x \in [x_H, \hat{x}]$. I must therefore define $\phi(x)$ differently for $x \in [x_L, x_H] \cup [\hat{x}, \infty)$. This means excluding new entry from the balance equation (36), and as a result, excluding the last term in (37). Taken together, the stationary distribution becomes the piece-wise function defined below:

$$\phi(x) = \begin{cases} C_1 exp[\gamma_1 x] + C_2 exp[\gamma_2 x] & x \in [x_L, x_H] \\ C_3 exp[\gamma_1 x] + C_4 exp[\gamma_2 x] + \phi_0(x) & x \in [x_H, \hat{x}] \\ C_5 exp[\gamma_1 x] + C_6 exp[\gamma_2 x] & x \in [\hat{x}, \infty) \end{cases} \tag{38}$$

To find the set of constants, I consider behavior at x_L, x_H, $\hat{x}$, and as $x \to \infty$. For details on stationary distribution derivation please see Appendix 5.

2D. Industry Quantity

In equilibrium, the industry quantity is constant, however there is still entry and exit. In order for total quantity to remain constant, the number of entrants must equal the number of exits at each time interval. This results in the following condition:

$$N[1 - G(X_H)] = \lambda Q + \frac{1}{2}\phi'(x_L)\sigma^2 \tag{39}$$

The left hand side holds the number of entrants at each instant. This is the number potential firms that receive high enough initial draw to enter, where $G(X)$ denotes the cumulative distribution function associated with $g(X)$. The right hand side has the number of exits at each instant. The first term represents exit by exogenous death and the second term represents exit by choice, which occurs when idiosyncratic revenue hits the threshold for optimal exit.

3D. Equilibrium Conditions

The stationary equilibrium consists of industry price P^*, industry quantity Q^*, and distribution $\phi^*(x)$, such that the following conditions hold:

1. Markets clear (1)
2. The entry decision cutoff, X_H^*, satisfies (33)
3. The exit decision cutoff, X_D^*, satisfies (26)
4. The stationary distribution satisfies (38)
5. Entry and exit flows balance, given by (39)
6. The coupon value satisfies (28)

E. Equilibrium: Domestic and foreign firms

The steps involved in finding equilibrium when domestic and foreign firms coexist closely resemble the domestic only case. I distinguish foreign firms from domestic through higher productivity and entry cost. I also make slight notation adjustments. For variables that differ between domestic and foreign, I denote domestic with subscript D and foreign with subscript F. I also represent the foreign idiosyncratic revenue shock by Y.

To account for higher foreign productivity, I adapt the domestic production function to reflect foreign firm production as such:

$$h_F(v) = \begin{cases} 0 & v = 0 \\ Z & v = 1 \end{cases} \tag{40}$$

This has the interpretation that foreign firms continuously use 1 unit of input to produce Z units of output flow. I keep the foreign cost function the same as the domestic, so is given by (4). Combining (4) and (18), I find the following expression for foreign profits:

$$\pi_F(Y, Q) = Y \cdot P \cdot h_F(v) - C(v) = Y \cdot Q^{-\epsilon} \cdot Z - C \tag{41}$$

The rest of the analysis of foreign firm entry and exit thresholds is the same as for domestic firms. Accordingly, the set of value matching and smooth pasting conditions determining the foreign entry and exit thresholds, Y_H and Y_L, are the foreign versions of (10)-(13). Note that the Q in these expressions still represents total industry quantity, as in the case of domestic only firms, but now total industry quantity is the sum of domestic and foreign quantities.

The next step is to determine equilibrium Q, as this will pin down both the domestic and foreign entry and exit thresholds. However, the presence of two types of firms complicates the analysis as it less clear how to derive the stationary distribution and specify the balanced flow conditions. The reason is that although domestic and foreign entry and exit have separate conditions, quantity has one joint condition, that total entry flow equals total exit flow. Since it is possible that foreign entry can replace domestic exit and vice versa, it becomes unclear how foreign and domestic entry and exit flows balance each other.

I argue that in equilibrium, a sufficiently high initial distribution upper bound, $\hat{X}$, ensures that foreign entry balances foreign exit, and domestic entry balances domestic exit. To see this, assume the opposite, that foreign entry flow does not balance foreign exit flow and without loss of generality that foreign entry flow is greater than foreign exit flow. Since total industry quantity must remain constant, domestic entry flow must be less than domestic exit flow. With enough time, domestic quantity will approach 0 and foreign firms will dominate the market. The foreign system of equilibrium conditions

will determine industry quantity. However, with sufficiently high $\hat{X}$, the domestic entry threshold, X_H, determined by this industry quantity will be less than $\hat{X}$. This means that some firms will receive initial idiosyncratic revenue high enough to warrant entry. This constitutes a contradiction since domestic quantity cannot both be 0 and positive. Therefore the initial assumption must be false, so in equilibrium foreign entry flow balances foreign exit and domestic entry flow balances domestic exit.

Now, assuming a sufficiently high $\hat{X}$, foreign entry balances foreign exit and domestic entry balances domestic exit. Then, the domestic and foreign stationary distributions each satisfy (16) and lead to industry balanced flow conditions. These are as follows:

$$N[1 - G(X_H)] = \lambda Q_D + \frac{1}{2}\phi'_D(x_L)\sigma^2 \tag{42}$$

$$N[1 - G(Y_H)] = \lambda Q_F + \frac{1}{2}\phi'_F(y_L)\sigma^2 \tag{43}$$

$$Q_D + Z \cdot Q_F = Q \tag{44}$$

Note that since Q_F stands for the mass of foreign firms and each foreign firm produces Z units of output, instead of 1, the total of domestic and foreign firm mass does not equal industry quantity. This is the reason why I multiply the number of foreign firms by Z in (44).

I now characterize the stationary equilibrium for when foreign and domestic firms coexist with industry price P^*, quantities Q_D^* and Q_F^*, and stationary distributions $\phi_D^*(x)$ and $\phi_F^*(x)$, such that the following conditions hold:

1. Markets clear (1)
2. The entry decision cutoffs, $X_H^*$and Y_H^*, satisfy foreign and domestic versions of ((33)
3. The exit decision cutoffs, X_D^* and Y_D^*, satisfy foreign and domestic versions (26)
4. Stationary distributions satisfy foreign and domestic versions of (38)
5. Entry and exit flows balance, given by (42)-(44)
6. Coupon values satisfy foreign and domestic versions of (28)

F. Model solution

In sum, I solve the following equations numerically in order to calculate equilibrium. There are two sets of these equations, one for domestic firms and one for foreign, except for (55), (56), and (57).

$$X_L = \frac{\beta_2}{\beta_2 - 1} \cdot \frac{C \cdot (\delta + \lambda)}{r + \lambda} \cdot Q^{\epsilon} \tag{45}$$

$$U(X,Q) = (1-\tau)[\frac{XQ^{-\epsilon}}{\delta+\lambda} - \frac{C}{r+\lambda}(1-\left(\frac{X}{X_L}\right)^{\beta_2}) - \frac{X_L Q^{-\epsilon}}{\delta+\lambda}\cdot\left(\frac{X}{X_L}\right)^{\beta_2}] \tag{46}$$

$$X_D = \frac{\beta_2}{\beta_2-1}\cdot\frac{(b+C)\cdot(\delta+\lambda)}{r+\lambda}\cdot Q^{\epsilon} \tag{47}$$

$$q(X) = \left(\frac{X}{X_D}\right)^{\beta_2} \tag{48}$$

$$V_L(X,Q,b) = U(X,Q) + \frac{\tau\cdot b}{r+\lambda}(1-q) - \alpha\cdot U(X_D,Q)\cdot q \tag{49}$$

The nonlinear equation for b:

$$\tau S^{-1}\cdot(b(X_H)+C)^{\beta_2+1} = b(X_H)(-\tau\beta_2+\tau-\alpha(1-\tau)\beta_2)+\tau C \tag{50}$$

Below is associated with the nonlinear equation for b:

$$S(X) = \left(\frac{X}{\frac{\beta_2}{\beta_2-1}\cdot\frac{(\delta+\lambda)}{r+\lambda}\cdot Q^{\epsilon}}\right)^{\beta_2} \tag{51}$$

Note that since b is a function of X, I solve the nonlinear equation defining b as functions of the two thresholds.

The nonlinear equation for X_H:

$$\beta_1[V_L(X_H,Q,b)-I] = (1-\tau)[\frac{X_H Q^{-\epsilon}}{\delta+\lambda}+\beta_2[\frac{C}{r+\lambda}-\frac{X_L Q^{-\epsilon}}{\delta+\lambda}]\left(\frac{X_H^{\beta_2}}{X_L^{\beta_2}}\right)]-\beta_2\left(\frac{X_H^{\beta_2}}{X_D^{\beta_2}}\right)(\frac{\tau\cdot b}{r+\lambda}+\alpha\cdot U(X_D,Q))+X_H\cdot\frac{\tau}{r+\lambda}(\tag{52}$$

Below are associated with the nonlinear equation for X_H:

$$\frac{db}{dX} = \frac{\beta_2 X^{-\beta_2-1}(b+C)^{\beta_2}R}{b^{-1}+R\cdot X^{-\beta_2}(b+C)^{\beta_2}[\beta_2(b+C)^{-1}-b^{-1}]} \tag{53}$$

$$R = \left(\frac{\beta_2}{\beta_2-1}\cdot\frac{\delta+\lambda}{r+\lambda}\cdot Q^{\epsilon}\right)^{\beta_2} \tag{54}$$

The quantity equation:

$$Q_D + Z \cdot Q_F = Q \tag{55}$$

Below are associated with the industry equilibrium:

$$\lambda Q_D = N[1 - G(X_H)] - \frac{1}{2}\phi'_D(x_D)\sigma^2 \tag{56}$$

$$\lambda Q_F = N[1 - G(Y_H)] - \frac{1}{2}\phi'_F(y_D)\sigma^2 \tag{57}$$

The solution for $\phi(x)$ is defined in equation (38) and reproduced below, with the derivation details and constant solutions in Appendix 5.

$$\phi(x) = \begin{cases} C_1 exp[\gamma_1 x] + C_2 exp[\gamma_2 x] & x \in [x_L, x_H] \\ C_3 exp[\gamma_1 x] + C_4 exp[\gamma_2 x] + \phi_0(x) & x \in [x_H, \hat{x}] \\ C_5 exp[\gamma_1 x] + C_6 exp[\gamma_2 x] & x \in [\hat{x}, \infty) \end{cases} \tag{58}$$

I will solve these equations for Q , X_H, and $b(X_H)$. The rest of the variables are defined as functions of these.

IV. Comparative statics

In this section I use comparative statics to examine the effect of foreign competition on leverage. I calculate effects of foreign competitiveness and trade policy uncertainty on leverage, firm profitability, industry profitability, entry/exit thresholds, and the probability of exit. Although leverage is the main outcome variable of interest, the others mentioned variables shed light on the story behind the result. Note that in all figures "CS" on the X axis represents the comparative static variable of interest and that I use the phrases "mass of firms" and "number of firms" interchangeably.

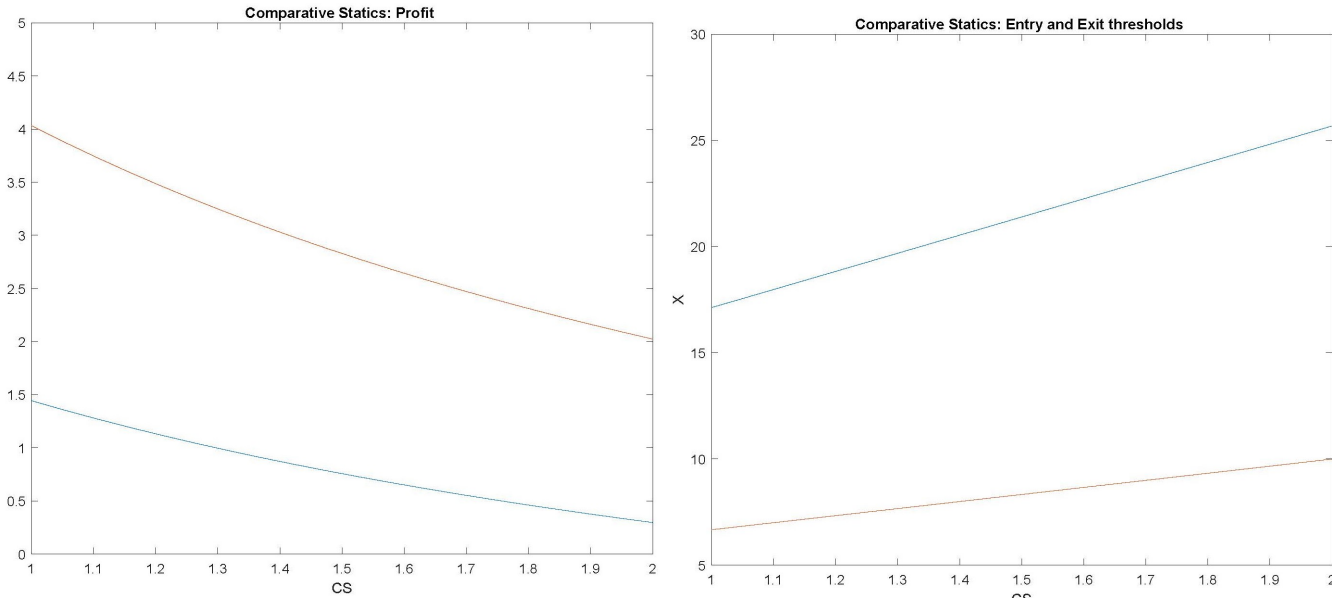
A. Foreign competitiveness

In section I examine how increased foreign competitiveness affects industry dynamics and domestic firm decisions. I only show results where increases in foreign productivity represent increases in foreign competitiveness since results are qualitatively the same when using other measures of competitiveness (i.e. decreases in foreign operating costs, decreases in entry costs, increases in cash flow growth)

Consider first the industry dynamics associated with an increase in foreign competitiveness. As foreign firms drive down the price, firms will be less profitable given the

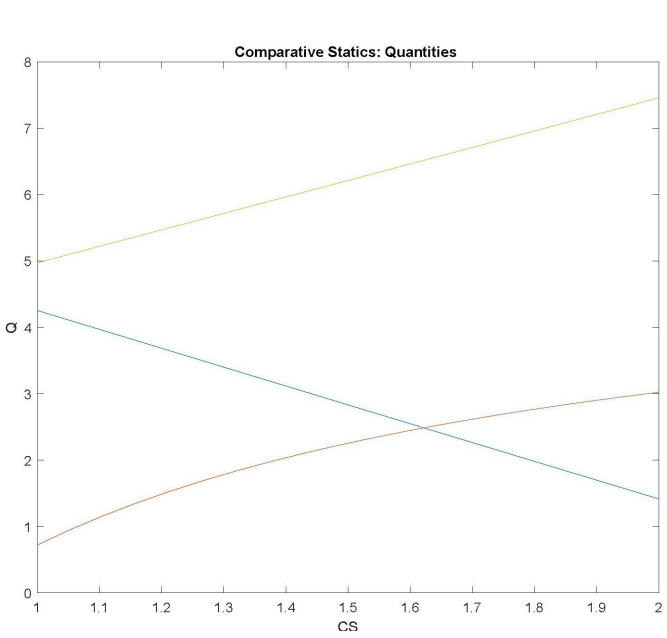
same idiosyncratic shock as evidenced by the profit function: $\pi = X \cdot Q^{-\epsilon} - C$. Firms will require a better initial draw to enter the industry and will require fewer bad shocks to exit. As such, as we increase foreign productivity, the entry and exit thresholds for domestic firms increase as well.

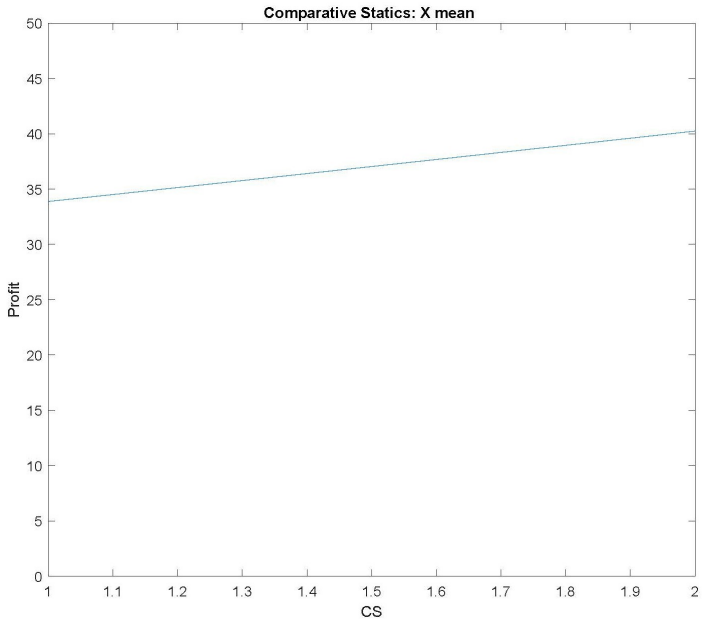
Right: Profitability given X , Left: Entry and exit thresholds



At the industry level, the story of entry and exit results in two competing effects for the impact on profitability. First, there is the profitability effect above. Second, there is a selection effect. Competition influences domestic firms with low shock realizations to exit and only domestic firms with high shock realizations to enter. This tells us that there will be fewer domestic firms (left chart below). Secondly, high shock firms will have greater representation in the domestic industry, resulting in a positive effect on the distribution over the idiosyncratic revenue shock (right chart below).

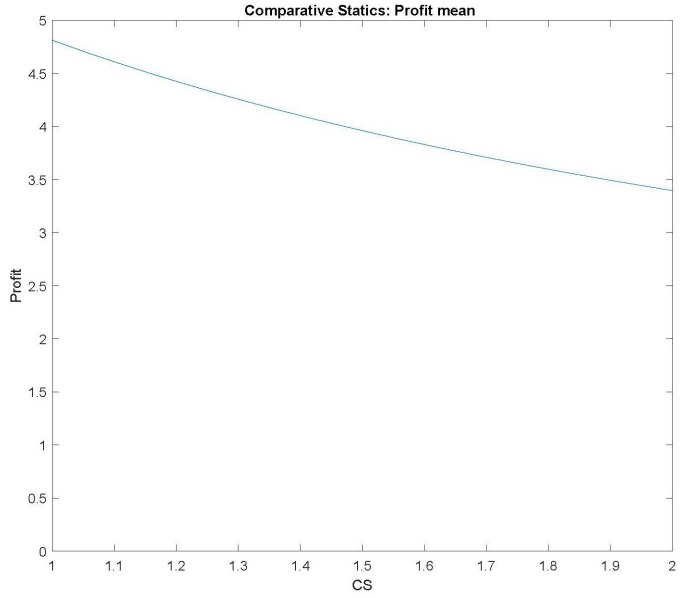
Left: Number of total firms (yellow), domestic firms (blue), and foreign firms (red), Right: Average X





Now, given that there are two competing effects, I use the model to see which dominates. The figure for profit mean shows the effect of foreign variable cost decreases on the domestic profit distribution. This indicates that model predicts the quantity effect to dominate the selection effect.

Mean industry profitability



Next I compute the domestic exit turnover rate, defined as the ratio of the mass of domestic exiting firms over the mass of domestic active firms. In stationary equilibrium, both masses are constant so the ratio is also constant. From the balance condition (17) we have the mass of domestic exiting firms, so dividing by Q gives the exit rate. Note that

in equilibrium the mass of entrants equals the mass of exits, resulting in the exit rate formula below:

$$\frac{\lambda Q + \frac{1}{2}\phi'(x_L)\sigma^2}{Q} = \frac{N[1 - G(X_H)]}{Q} \tag{59}$$

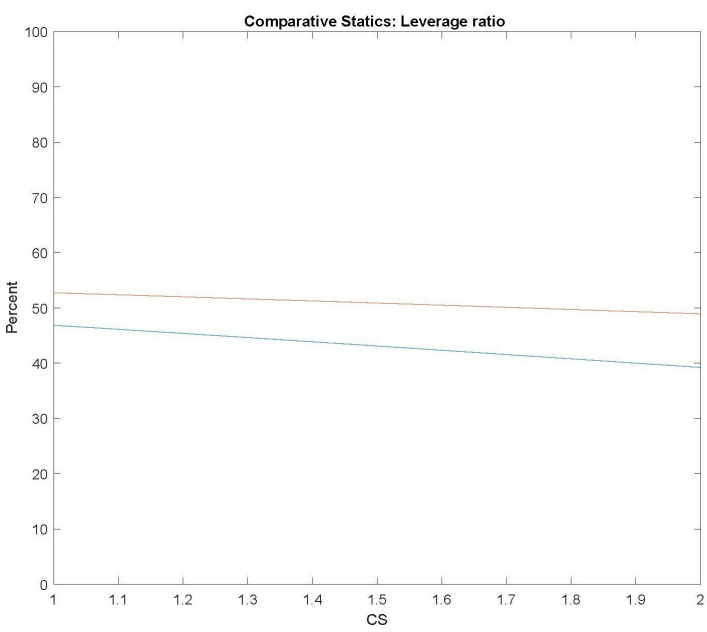
From the discussion on domestic quantity, the denominator for the exit rate expression decreases. Similarly, since the entry threshold increases, the numerator decreases. Whichever dominates will determine the effect on the exit rate.

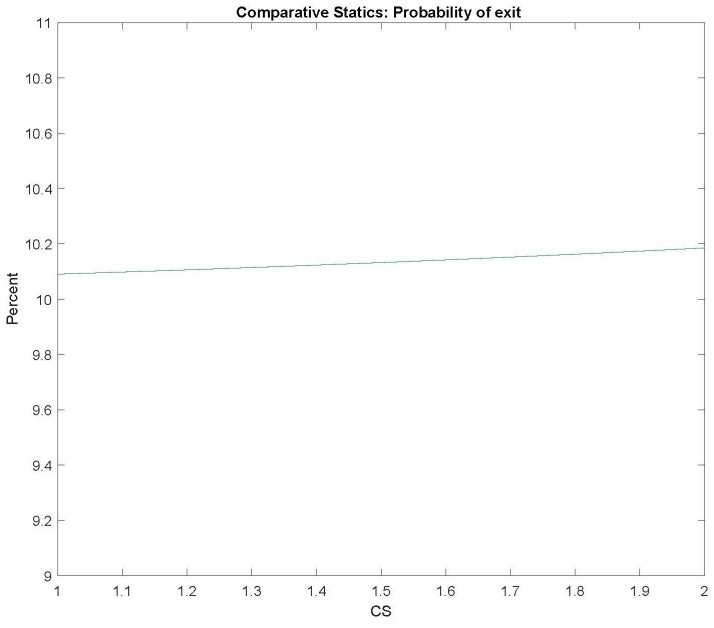
Next, I compute leverage, defined by the following formula:

$$Leverage = \frac{D(X,b)}{V_L(X,Q,b)}$$

Not surprisingly, since firm profitability decreases and the exit rate increases with foreign competition and optimal leverage decreases. This holds for both the firm and industry level.

Left: Leverage given X, Right: Exit rate





B. Uncertainty

1B. Representing Uncertainty

Next I capture uncertainty in foreign competition in the model, where a potential foreign supply shock to the industry brings additional uncertainty in prices and future revenue.

But simply labeling the volatility parameter as uncertainty is not appropriate because firms do not experience a corresponding increase in realized cash flow variation. As such, the model needs introduce uncertainty in firm's future cash flows, without an associated increase in realized cash flow variation. For this reason I separate the volatility parameter into two, one for firm decisions and one for industry equilibrium, breaking the link between the volatility in firm decisions and volatility in actual cash flow movement. In other words, the equilibrium conditions that rely on movements in the mass of firms are based one volatility parameter, while firm decisions are based on a higher one. Accordingly, for comparative statics increases in uncertainty are defined as increases in the gap between the volatility parameter governing firm decisions and the volatility parameter governing actual cash flow movements and the stationary distribution.

I next mathematically justify why separating the volatility parameter into two separate parameters captures trade policy uncertainty. To do this, I incorporate uncertainty into the firm profit function. I conjecture that this will result in altering the idiosyncratic shock process underlying firm decisions, compared to the one governing realized cash flow variation and the stationary distribution: $dX^{Alt} = \alpha^{Alt} X dt + \sigma^{Alt} X dW$

To set the stage, I first do this using a simple method and second show that a more rigorous version has the same result. Here, I simply add two extra terms to the firm's revenue dynamics, reflecting the impact of the potential trade event. The first term represents the expected proportional price change and the second term represents uncertainty surrounding the price change. This is denoted below:

$$d(XP) = PdX + k_1 Pdt + k_2 PdW = P((\alpha + k_1)Xdt + (\sigma + k_2)XdW) = PdX^{Alt}$$

$$dX^{Alt} = \alpha^{Alt} X dt + \sigma^{Alt} X dW$$
$$\alpha^{Alt} = \alpha + k_1$$
$$\sigma^{Alt} = \sigma + k_2$$

Now, moving to the firm value calculations, the Bellman equation defining levered firm value is below:

$$rL(X, Q, b)dt = \pi(X, Q, b)dt + E[dL(X, Q, b)]$$

When calculating the expectation, we observe that X^{Alt} is the only state variable, so the resulting pde is below:

$$(r + \lambda) \cdot U = \tfrac{1}{2}\sigma_{Alt}^2 U_{XX} X^2 + \alpha_{Alt} U_X X + \pi$$

Unlevered an inactive firm value follow similar procedures. Subsequent firm value derivations as well as leverage and entry/exit decisions are then based on the parameters of the alternate idiosyncratic shock process. Yet, when calculating the stationary distribution of firms and resulting industry quantity, we use the shock process governing realized cash flow evolution. We can then interpret the difference between the alternate and realized shock parameters as trade policy uncertainty.

Next, I use a more rigorous approach that explicitly models the trade policy event. It justifies the simple version because it results in an analogous alternate idiosyncratic shock process and subsequent firm value derivations. To do this, I use an approach similar to a continuous time version of Handley and Limao (2017) where I treat trade policy as an arrival process. The main difference from Handley and Limao (2017) lies in the fact that they study how uncertainty changes foreign exporter decisions, where I am primarily interested in domestic import competing firm decisions. For this reason, I set the arrival process to act on the resulting industry price, instead of their approach that sets the process to act directly on tariffs.

Specifically, the trade event is an arrival process that occurs with constant probability η. If the event occurs, there is a distribution over the resulting industry price, where k_1 denotes the expected price change and k_2 the uncertainty surrounding the expectation. This is depicted below:

$$dP = \begin{cases} 0 & \text{with probability } (1-\eta) \\ k_1 P dt + k_2 P dW & \text{with probability } \eta \end{cases}$$

Similar to the simple version, we can derive an expression for firm revenue:

$$d(XP) = PdX + XdP + dXdP = P((\alpha + k_1\eta + \sigma k_2 \eta)Xdt + \sigma X dW + k_2 \eta X dW)$$

The Bellman equation for the levered firm value is repeated below:

$$rL(X,Q,b)dt = \pi(X,Q,b)dt + E[dL(X,Q,b)]$$

Note that we since X enters linearly with P to the revenue expression, we can expand the expectation using only one state variable. This results in the following pde:

$$(r+\lambda)\cdot U = \tfrac{1}{2}(\sigma^2 + k_2^2\eta^2 + 2\sigma k_2 \eta)U_{XX}X^2 + (\alpha + k_1\eta + \sigma k_2\eta)U_X X + \pi$$

Now we can define an alternate shock process that results in this same pde:

$$dX^{Alt} = \alpha^{Alt} X dt + \sigma^{Alt} X dW$$

$$\alpha^{Alt} = \alpha + k_1\eta + \sigma k_2 \eta$$
$$\sigma^{Alt} = \sqrt{\sigma^2 + k_2^2\eta^2 + 2\sigma k_2 \eta}$$

Comparing the original pde to the one with trade uncertainty, we see that the new firm value calculations as well as the entry/exit and leverage decisions will be based on the alternate shock process. However, the realized cash flow given that no event has occurred will remain based on the original shock process parameters.

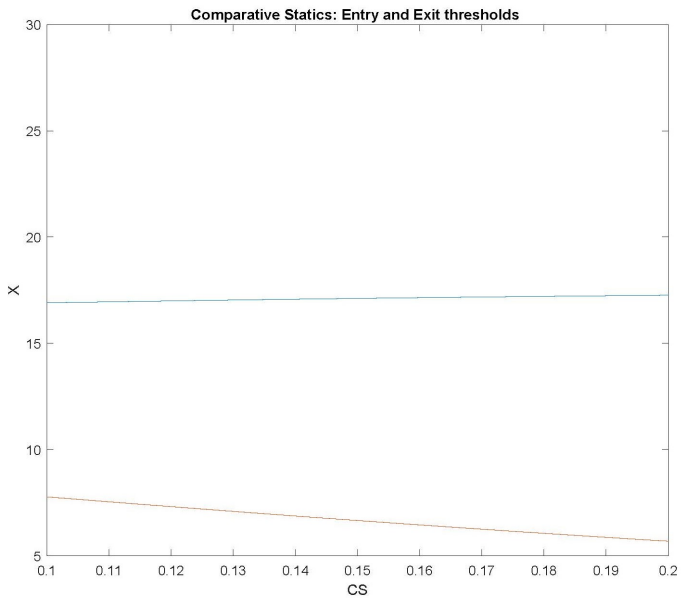
Original: $(r+\lambda)\cdot U = \frac{1}{2}\sigma^2 U_{XX} X^2 + \alpha U_X X + \pi$
With trade uncertainty: $(r+\lambda)\cdot U = \frac{1}{2}\sigma_{Alt}^2 U_{XX} X^2 + \alpha_{Alt} U_X X + \pi$

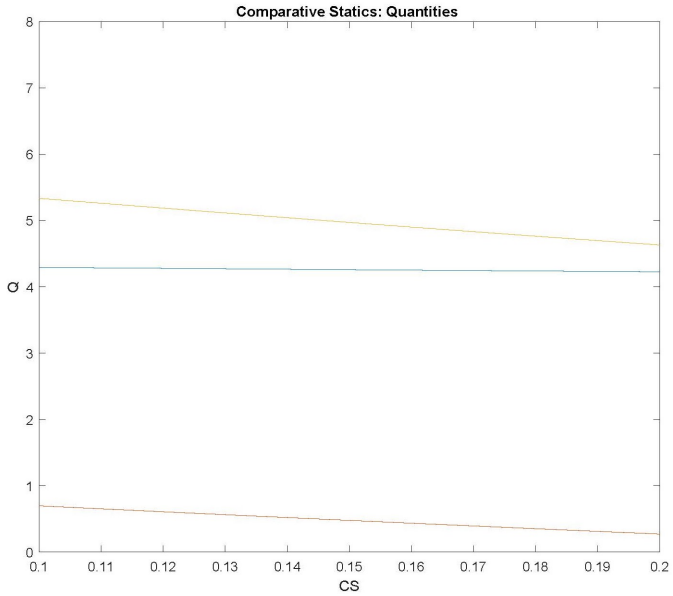
As in the simple version, the difference between the alternate and original parameters represents trade policy uncertainty in the model. Comparative statics analyzing uncertainty will therefore vary this difference. Specifically, I will hold fixed the originals while varying the alternates.

2B. Comparative Statics

Below shows that with an increase in uncertainty, firms wait longer to enter and exit (left panel). For foreign firms, this deters a greater mass of potential entrants than exits, resulting in fewer foreign firms. From this, we see that the model predicts that uncertainty will have a stronger effect on the number of firms for the type of firm that controls a lower industry share. I constrain this to be the foreign firm type since it is true in the data. Particularly, Chinese import penetration to the U.S. manufacturing industry is well under one half. The right panel shows that uncertainty results in fewer foreign firms in equilibrium, which props up prices for domestic firms. Here the strong decrease in foreign firms counteracts domestic firms' reluctance to enter, leaving the number of domestic firms relatively unchanged.

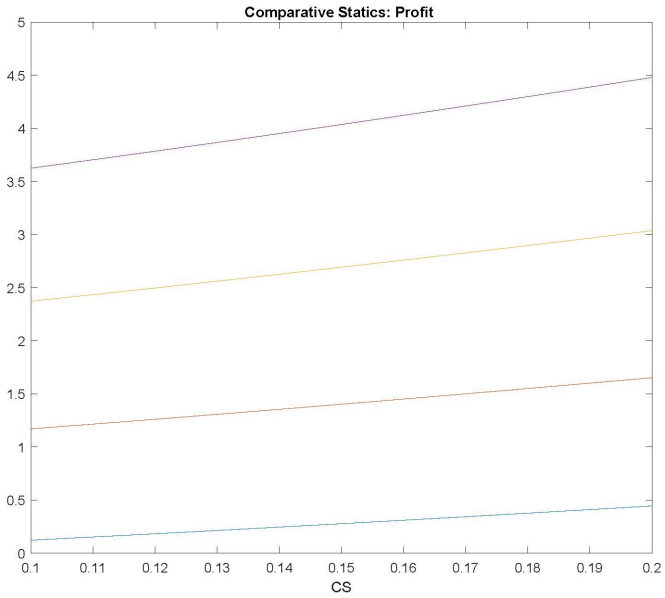
Left: Entry and exit thresholds, Right: Mass of total firms, domestic firms, and foreign firms (top to bottom)

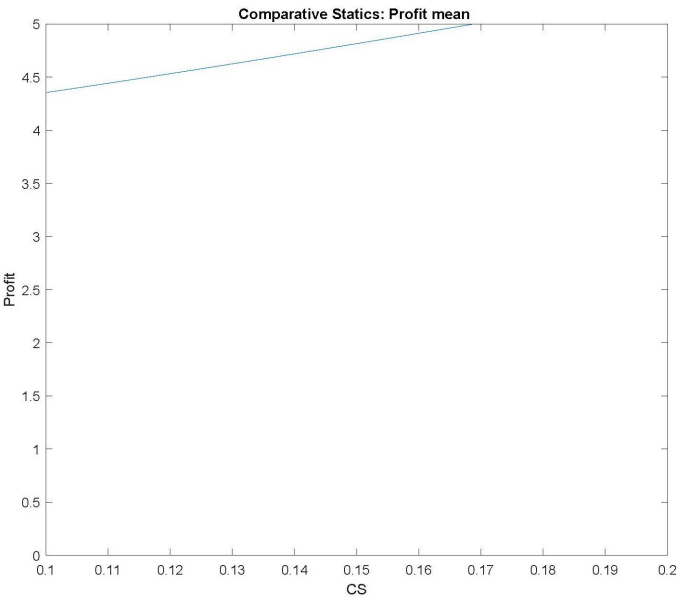




In the left panel, with the decrease in the total quantity of firms and its implied price increase, profitability given X increases. Since the average X remains unchanged, this results in an increase in mean industry profitability as well.

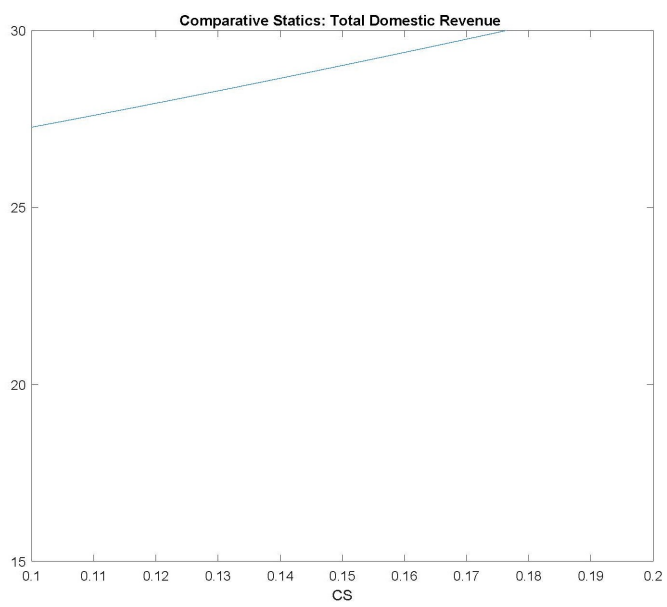
Left: Profitability given X , Right: Mean industry profitability

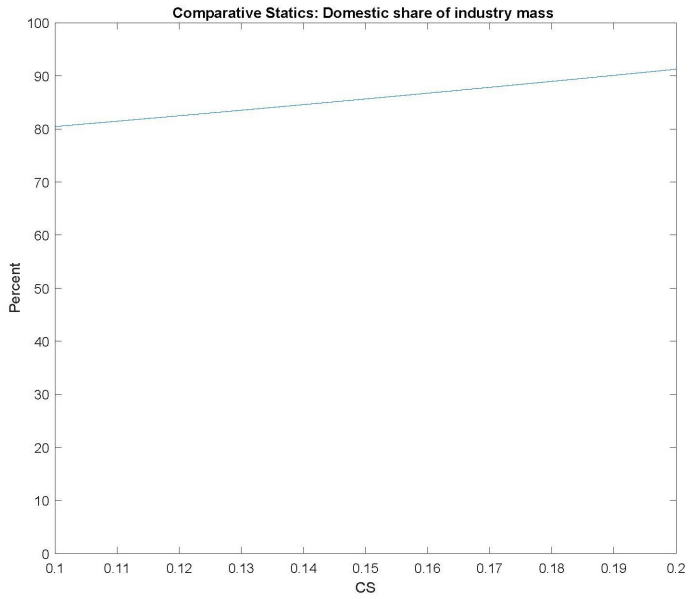




The increase in total domestic revenue follow from profitability as the mean X remains unchanged, the number of domestic firms remains unchanged, and the price increases. The increase in domestic industry share follows from the decrease in foreign firms.

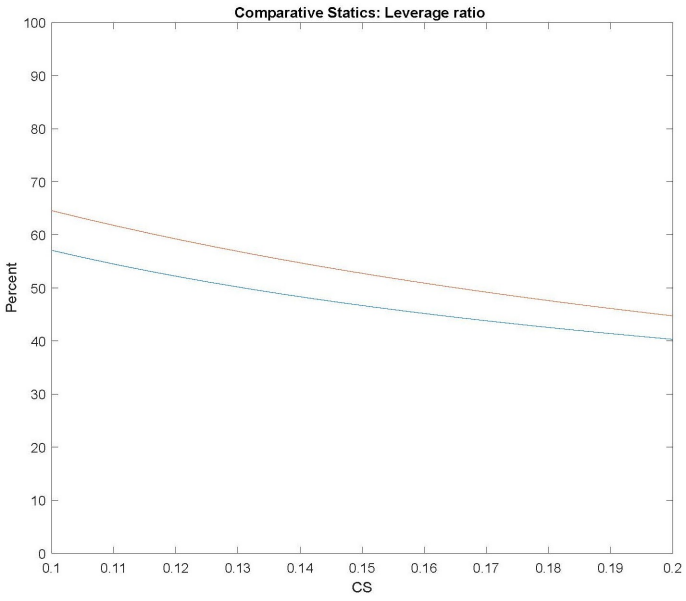
Left: Total domestic revenue, Right: Share of industry revenue

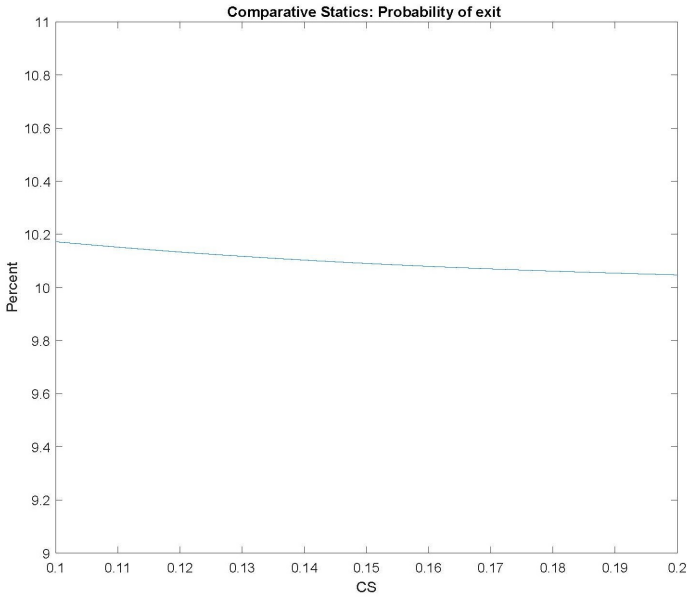




Below shows effects on leverage and the exit rate. The exit rate decreases with an increase in trade policy uncertainty because uncertainty pushes down the exit threshold. For leverage, there are three competing effects. The lower exit rate and higher profitability would have a positive effect, while the threat of increased competition would have a negative effect. The panels below suggest that the latter effect dominates the former, resulting in a negative effect of trade policy uncertainty on leverage.

Left: Leverage given X, Right: Exit rate





III. Empirical Analysis

A. Data and measures

I obtain annual US firm level fundamental data from Compustat. Summary statistics for key variables of interest are detailed in Appendix 1. Gross book leverage is defined as the sum debt in current liabilities and long term debt divided by total assets. Net book leverage subtracts cash and short term investments from the sum of debt in current liabilities and long term debt and divides by the numerator. Market leverage is the sum of debt in current liabilities and long term debt divided by the sum of total assets plus market equity minus book equity.

1A. Trade exposure

I follow prior work that uses shipping costs as a measure trade exposure (Barrot, Loualiche, Sauvagnat (2017)). I construct shipping costs using annual industry level data at the 4-digit SIC level over 1974-2015 from Peter Schott's website. This measure is defined as the difference between the Cost-Insurance-Freight (CIF) and the Free-on-Board (FOB) value divided by the Free-on-Board (FOB) value. The CIF value of goods differs from the FOB value in that it includes costs associated with shipment (such as insurance, shipping container costs, loading, etc.) and the value of the goods, while the FOB only includes the value of the goods. In other words, the shipping cost measure is the number of cents per dollar of goods that the exporter pays to deliver the goods.

The original data comes at the industry-trading partner level, I sum the CIF and FOB values across trading partners. However, it is possible to construct shipping costs spe-

cific to one trading partner. I create China specific shipping costs, since recent Chinese trade activity has been a major source of import competition in the US. The shipping costs for China would therefore play a more significant role in influencing import competition compared to those for a country uninterested in exporting to the US.

Appendix 1 displays a chart showing the cross-sectional and time series attributes of both shipping cost measures. Over time, shipping costs have a slight downwards trend and within the cross-section there is substantial industry heterogeneity. The China specific shipping costs are more volatile and have a sharper downwards trend relative to the aggregate ones.

The logic for using shipping costs to represent trade exposure is that foreign firms facing lower shipping costs will be more likely to export. This brings additional competition to domestic firms. Hummels (2007) argues that heavy goods are more cumbersome to ship and therefore associated with higher shipping costs. Accordingly, domestic firms in industries with lower shipping cost industries should face more foreign competition.

A number of papers have shown that shipping costs are associated with levels of various kinds of economic activity. These include a negative association with imports and exports as well as a positive association with employment and output. These findings are evidence that shipping costs meaningfully deter trade and shield domestic industries from foreign competition.

Shipping costs are not only associated with levels of economic activity, but also with changes in economic activity. Barrot et al (2016) find a negative association with Chinese import growth. Since Chinese import growth was driven primarily by productivity increases (Zhu 2012), they argue that a given foreign productivity shock induces a larger foreign export increase in lower shipping cost industries. This constitutes evidence that shipping costs capture exposure to foreign competition. Moreover, prior empirical work using shipping costs as a measure of trade exposure have found meaningful connections with domestic financial variables. Barrot et al (2016) document an equity risk premium on firms in industries with low shipping costs and Barrot et al (2017) find a negative relationship between shipping costs and household debt growth.

2A. Trade Policy Uncertainty

I use a period of several years prior to China's accession to the WTO in 2001 as a measure trade policy uncertainty. First, China's WTO accession was an important event for import competing firms. The event significantly increased Chinese exports to the U.S., bringing harsher competition to U.S. manufacturing firms. Notably, Autor et al (2012) show that the growth rate in import penetration jumps directly following the event.

Second, the political history behind US-China trade relations around the WTO accession indicates that there was considerable uncertainty directly prior to 2001. Using this time period strategy would be problematic if accession decision and benefits associated

with accession happened before 2001, as the event would have effectively realized prior to its official enactment date. Instead, the U.S. legislative act granting China permanent normal trade relations was only passed in 2000 and even then it was contingent upon China's successful WTO accession. Further, impediments to WTO negotiations as well as a plane collision prompted Congress to vote in 2001 on revoking China's MFN status. It was only when China successful joined the WTO later on in 2001 that the U.S. granted permanent normal trade relations.[1]

Third, a recent literature has found that the trade policy uncertainty reduction following China's WTO accession is large and important. In their model, Handley and Limao (2017) estimate changes in uncertainty parameters from WTO enaction to years later and find significant reductions. A number of papers also find that Chinese exports increased more in industries with larger uncertainty reductions (Handley and Limao 2017, Feng et al 2017, Crowley et al 2018). In model counterfactuals, Crowley et al (2018), estimates that this WTO uncertainty reduction effect on Chinese export entry was large. Handley and Limao (2017) find similar counterfactual results for China's import penetration to the U.S.

B. Empirical Approach

I use a difference in difference method to empirically analyzing the relationship between foreign competition and leverage. For the first difference I exploit variation in trade exposure across industries. Since shipping costs act as a barrier to trade, domestic firms in industries with low shipping costs will have more foreign competition. I look at the cross-sectional relationship between shipping costs and leverage. A positive sign on this coefficient suggests a negative association between foreign competition and leverage. However, a second difference is necessary to reduce endogeneity and to separate two channels of interest underlying foreign competition.

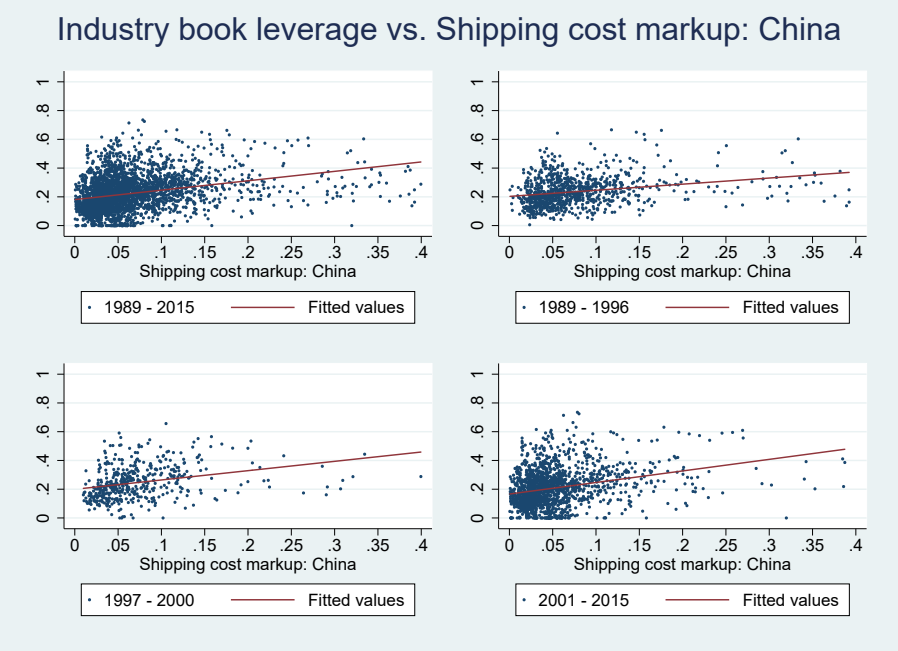
For the second difference, I exploit variation in trade shocks surrounding China's WTO accession. I divide the sample into three time periods, where each time period corresponds with a new trade shock. The first period is 1989-1996, which experienced the initial rise in Chinese exporting activity. The second period is 1997-2000, which experienced an increase in trade policy uncertainty. The last period is 2001-2015, which experienced both a reduction in trade policy uncertainty and increase in Chinese export competitiveness. I examine changes in the cross-sectional relationship between shipping costs and leverage across these changes in trade shocks. Here, I use the fact that exports to low shipping cost industries are more sensitive to foreign productivity shocks and extend the logic to trade shocks more generally. In other words, I am using shipping costs as a indicator of export elasticity to trade shocks.

[1] Handley and Limao (2017)

An increase in the relationship between shipping costs and leverage will signify a negative association between the trade shock of interest and leverage. Essentially, I am conducting two separate difference and difference tests. The first is the difference between the first and second periods. An increase in the relationship between shipping costs and leverage will signal a negative association between trade policy uncertainty and leverage. The second is the difference between the second and third periods. An increase in the relationship between shipping costs and leverage will signal a negative association in the net effect of trade policy uncertainty reduction and WTO induced foreign competitiveness on leverage.

C. Suggestive Correlations

I first explore simple correlations between import competition and leverage in the data. The figure below summarizes the cross-sectional relationship between the trade exposure measure and leverage and how the relationship has changed over time. I use average gross book leverage and China specific shipping costs. Each data point represents a 4 digit SIC industry in a particular year. Although the analysis will be conducted at the firm level, it is clearer to visualize the data at the industry level. This is because using firms generates vertical lines in the scatter plots, making it harder to distinguish among observations and see the pattern.



The upper left panel shows that there is a positive correlation between shipping costs and leverage using the entire sample period. This means that the average firm in indus-

tries with higher trade exposure are more likely to have lower leverage. The rest of the figure examines changes in the association between trade exposure and leverage during periods of increased foreign competitiveness. The underlying logic is that when foreign firms increase exports, high trade exposure industries receive more import competition than low trade exposure industries.

The upper right panel shows a positive relationship between shipping costs and leverage in the period 1, meaning a negative association between foreign competition and leverage during China's initial export growth. Next, the lower left panel shows the period 2, the uncertainty period. The lower left panel shows a sharper positive connection between shipping costs and leverage in period 2, compared to period 1. I interpret this as suggestive evidence of a negative association between trade policy uncertainty and leverage. Lastly, the lower right panel shows period 3, where there was trade policy uncertainty reduction as well as an increase in foreign competitiveness due to the WTO. The relationship appears stronger than period 1 and unchanged compared to the second period. I interpret this as suggestive evidence that trade policy uncertainty reduction is positively associated with leverage and foreign competitiveness is negatively associated with leverage. To address robustness, Appendix 2 repeats this figure using net book leverage and market leverage. These patterns are additionally robust to perturbations in the period definitions, such as including 1996 in period 2 or truncating period 3 to end in 2008.

D. Regression Results

For a more rigorous approach, I conduct a regression analysis to show that these trends do not disappear when adding well-known leverage determinants and that the differences in coefficients across the identified periods are statistically significant. Below is the specification:

$$Leverage_{ijt} = \alpha + \sum_{j=1}^{3} \beta_j \cdot period_j \cdot SC_{jt} + \gamma \cdot controls_{ijt} + \tau_t + \eta_j + \epsilon_{ijt}$$

SC represents shipping costs. I normalize the shipping cost variable, so that the economic interpretation is the effect of 1 standard deviation in shipping costs on leverage. The coefficients on period-shipping cost interaction terms are the ones of interest, where the period definitions were laid out in the previous section. Controls represent a vector of controls. These include known leverage determinants: market to book ratio, total sales, net tangible assets, capital expenditures, and market to book ratio. Following Xu (2012), these controls also include domestic competition related variables, firm market share and industry Herfindahl index. I calculate the Herfindahl index as the sum of squared revenue shares of all Compustat firms in a given SIC 4-digit industry. The last three terms are the year dummies, industry dummies, and error term.

The table below shows the regression output:

		Gross Book Leverage			Net Book Leverage			Market Leverage		
*=10% significance **=5% significance ***=1% significance		OLS	Firm controls	Year + industry dummies + firm controls	OLS	Firm controls	Year + industry dummies + firm controls	OLS	Firm controls	Year + industry dummies + firm controls
shipping cost markup	coef	3.36	1.05	-0.07	9.17	2.22	-0.72	3.3	1.31	0.16
1989-1996	se	0.18	0.17	0.21	0.36	0.31	0.36	0.14	0.14	0.16
	star	***	***		***	***	**	***	***	
	t	19.04	6.1	-0.34	25.43	7.23	-2.02	23.55	9.55	1
shipping cost markup	coef	6.83	2.87	1.15	18.86	6.45	1.64	6.94	3.52	1.68
1997-2000	se	0.33	0.32	0.37	0.67	0.57	0.62	0.26	0.25	0.29
	star	***	***	***	***	***	***	***	***	***
	t	20.91	8.97	3.11	28.18	11.29	2.63	26.66	13.91	5.86
shipping cost markup	coef	5.32	3.37	0.42	20.35	12.5	2.15	4.97	3.11	0.68
2001-2015	se	0.2	0.19	0.29	0.4	0.34	0.48	0.15	0.15	0.22
	star	***	***		***	***	***	***	***	***
	t	27.28	17.5	1.46	50.97	36.43	4.45	32.08	20.55	3.09
Period 2 - Period 1	sign	+	+	+	+	+	+	+	+	+
	star	***	***	***	***	***	***	***	***	***
Period 3 - Period 2	sign	-	+	-	+	+	+	-	-	-
	star	***		*	*	***		***		***

The most important features are highlighted in red. These show the direction and statistical significance of the difference in shipping cost interactions with the period dummy. From period 1 to period 2, shipping costs become more positively associated with leverage, meaning that trade exposure becomes more negatively associated with leverage. This difference is statistically significant the 1 percent level. However, a different result emerges when looking at the difference between periods 3 and 2. Depending on the measure, shipping costs either become more negatively associated with leverage or the relationship remains unchanged.

In the context of the trade-off theory, the difference in periods 3 and 2 is counter-intuitive. One would expect that the WTO would be a negative shock to profitability that would induce firms to decrease their financial leverage, reflecting the higher probability of default and therefore higher bankruptcy costs of debt. Interestingly, this behavior is consistent with both Xu (2012), since trade exposure and leverage are negatively associated, and Baggs and Brander (2006), since the relationship becomes weaker (i.e. more positive) following a trade policy event.

D. Discussion

I now discuss the consistency between the empirical results and model predictions. The first result is a stronger negative relationship between trade exposure and domestic firm leverage in the WTO uncertainty period. Since increasing the uncertainty parameter in the model generates a negative leverage impact, the model matches the finding. The underlying story is that firms face higher future bankruptcy probability, despite the fact that firms are contemporaneously more profitable and have lower exit probabilities. The future bankruptcy concerns raise the expected bankruptcy costs of debt relative to the

tax benefits of debt. Firms can increase firm value through reducing their reliance on debt, so optimally choose to decrease leverage.

The second result is a slightly weaker relationship between trade exposure and leverage after WTO accession, despite an increase in foreign competitiveness. This result echos the literature's disagreement. Recall that the paper that found a positive association between leverage and foreign competition involved a trade policy event, while the other with the negative association did not. The model offers an explanation through uncertainty reduction. The model suggests that a positive effect of uncertainty reduction on leverage pushes against the negative effect of foreign competitiveness on leverage. Even though foreign competition reduces domestic profitability, through uncertainty reduction, a positive sign for the effect of leverage is still consistent with the trade-off theory.

V. Conclusion

I investigate the relationship between import competition and leverage. Prior empirical evidence is inconsistent and little theory exists. I use shipping cost data and Chinese competition shocks to show empirically that the negative association between import competition and leverage becomes stronger during a time of uncertainty, but does not during the period of realized increased foreign competitiveness. I build a model of industry equilibrium with entry and exit that reconciles empirical findings once differentiating between two channels underlying the increases in foreign competition: foreign competitiveness and trade policy uncertainty. Lastly, opportunities to strengthen this analysis include quantifying the effect of each channel on leverage and examining a domestic refinancing cost friction as an additional mechanism.

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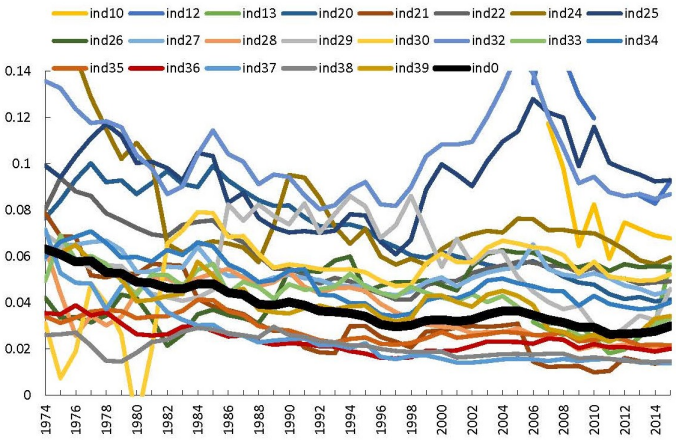
Appendix 1: Summary statistics

Below are summary statistics for Compustat firm variables and shipping costs. In the shipping cost graphs, the colored lines represent shipping costs aggregated to the 2-digit SIC level and the thick black line is aggregated to the country level.

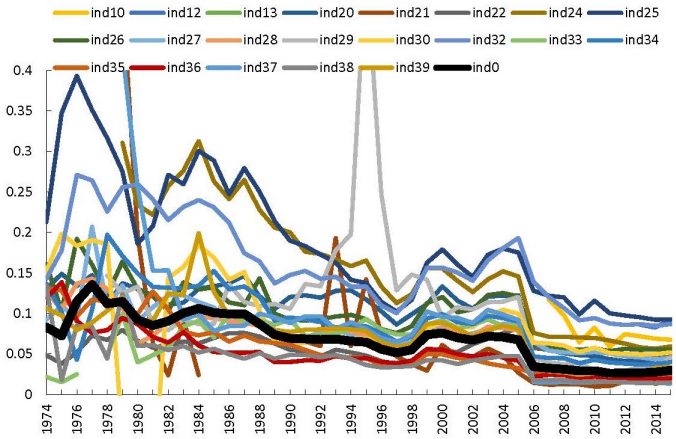
Compustat firm variables:

variable	mean	median	sd	min	max	count
gross book leverage	0.219	0.179	0.209	0.000	1.000	85604
net book leverage	0.005	0.062	0.393	-1.000	1.000	86136
market leverage	0.219	0.133	0.241	0.000	1.000	76595
operating income/total assets	-0.739	0.093	27.756	-5093.000	13.334	88769

Shipping costs: aggregate

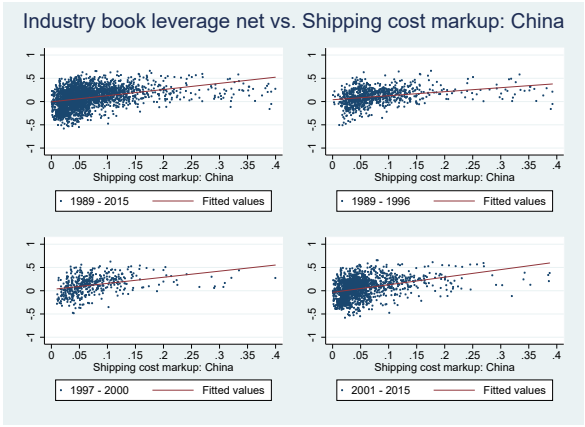


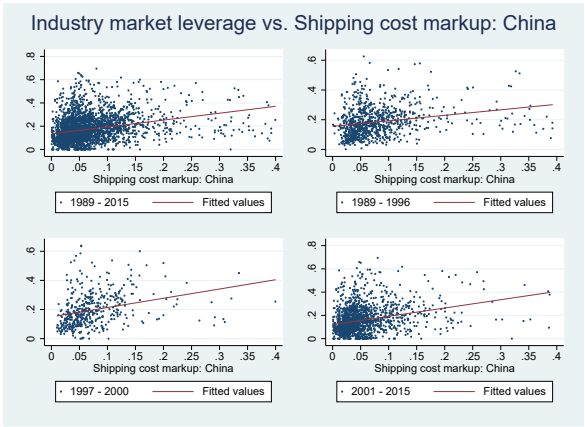
Shipping costs: China specific



Appendix 2: Shipping costs vs. leverage

The relationship between shipping costs and leverage appears robust to different leverage definitions. The positive relationship seems to strengthen more in the 1997-2000 period compared to the 2001-2015 period.





Appendix 3: Coupon value derivation

I use just the terms with b and choose the b value that maximizes the value of the levered firm.

I have 3 terms with b:

$$\frac{\tau \cdot b}{r+\lambda}(1-q) - \alpha \cdot U(X_D, Q) \cdot q = \frac{\tau \cdot b}{r+\lambda} - q\frac{\tau \cdot b}{r+\lambda} - \alpha \cdot U(X_D, Q) \cdot q$$

The derivative of the first term is:

$$\frac{\tau}{r+\lambda} \tag{60}$$

$X_D = \frac{\beta_2}{\beta_2 - 1} \cdot \frac{(b+C)\cdot(\delta+\lambda)}{r+\lambda} \cdot Q^{\epsilon}$
$q = \left(\frac{X}{X_D}\right)^{\beta_2}$
The second term is:

$$-\left(\frac{X}{X_D}\right)^{\beta_2} \frac{\tau \cdot b}{r+\lambda} = -(b+C)^{-\beta_2} \left(\frac{X}{\frac{\beta_2}{\beta_2-1}\cdot\frac{\cdot(\delta+\lambda)}{r+\lambda}\cdot Q^{\epsilon}}\right)^{\beta_2} \frac{\tau \cdot b}{r+\lambda} = -(b+C)^{-\beta_2} \frac{\tau \cdot b}{r+\lambda} S$$

where

$$S = \left(\frac{X}{\frac{\beta_2}{\beta_2-1}\cdot\frac{\cdot(\delta+\lambda)}{r+\lambda}\cdot Q^{\epsilon}}\right)^{\beta_2}$$

The derivative of the second term is:

$$\beta_2(b+C)^{-\beta_2-1}\frac{\tau \cdot b}{r+\lambda}S - (b+C)^{-\beta_2}\frac{\tau}{r+\lambda}S \tag{61}$$

The third term is:

$$-\alpha \cdot U(X_D, Q) \cdot q$$

where $U(X_D, Q) = (1-\tau)[\frac{X_D Q^{-\epsilon}}{\delta+\lambda} - \frac{C}{r+\lambda}(1 - \left(\frac{X_D}{X_L}\right)^{\beta_2}) - \frac{X_L Q^{-\epsilon}}{\delta+\lambda} \cdot \left(\frac{X_D}{X_L}\right)^{\beta_2}]$

so multiplying by q I get:

$$(1-\tau)[\left(\frac{X}{X_D}\right)^{\beta_2} \frac{X_D Q^{-\epsilon}}{\delta+\lambda} - \left(\frac{X}{X_D}\right)^{\beta_2} \frac{C}{r+\lambda}(1 - \left(\frac{X_D}{X_L}\right)^{\beta_2}) - \left(\frac{X}{X_D}\right)^{\beta_2} \frac{X_L Q^{-\epsilon}}{\delta+\lambda} \cdot \left(\frac{X_D}{X_L}\right)^{\beta_2}]$$

$$(1-\tau)[\left(\frac{X}{X_D}\right)^{\beta_2} \frac{X_D Q^{-\epsilon}}{\delta+\lambda} - \frac{C}{r+\lambda}(\left(\frac{X}{X_D}\right)^{\beta_2} - \left(\frac{X}{X_L}\right)^{\beta_2}) - \left(\frac{X}{X_L}\right)^{\beta_2} \frac{X_L Q^{-\epsilon}}{\delta+\lambda}]$$

Get rid of the terms without Xd:

$(1-\tau)[\left(\frac{X}{X_D}\right)^{\beta_2}\frac{X_D Q^{-\epsilon}}{\delta+\lambda} - \frac{C}{r+\lambda}\left(\frac{X}{X_D}\right)^{\beta_2}]$

$(1-\tau)X^{\beta_2}[X_D^{-\beta_2+1}\frac{Q^{-\epsilon}}{\delta+\lambda} - X_D^{-\beta_2}\frac{C}{r+\lambda}]$

Replacing in for Xd:

$(1-\tau)X^{\beta_2}[(\frac{\beta_2}{\beta_2-1}\cdot\frac{(b+C)\cdot(\delta+\lambda)}{r+\lambda}\cdot Q^{\epsilon})^{-\beta_2+1}\frac{Q^{-\epsilon}}{\delta+\lambda} - (\frac{\beta_2}{\beta_2-1}\cdot\frac{(b+C)\cdot(\delta+\lambda)}{r+\lambda}\cdot Q^{\epsilon})^{-\beta_2}\frac{C}{r+\lambda}]$

Pulling out the b:

$(1-\tau)X^{\beta_2}[(b+C)^{-\beta_2+1}(\frac{\beta_2}{\beta_2-1}\cdot\frac{(\delta+\lambda)}{r+\lambda}\cdot Q^{\epsilon})^{-\beta_2+1}\frac{Q^{-\epsilon}}{\delta+\lambda} - (b+C)^{-\beta_2}(\frac{\beta_2}{\beta_2-1}\cdot\frac{(\delta+\lambda)}{r+\lambda}\cdot Q^{\epsilon})^{-\beta_2}\frac{C}{r+\lambda}]$

Then the derivative of the third term:

$(1-\tau)X^{\beta_2}[(-\beta_2+1)(b+C)^{-\beta_2}(\frac{\beta_2}{\beta_2-1}\cdot\frac{(\delta+\lambda)}{r+\lambda}\cdot Q^{\epsilon})^{-\beta_2+1}\frac{Q^{-\epsilon}}{\delta+\lambda} + \beta_2(b+C)^{-\beta_2-1}(\frac{\beta_2}{\beta_2-1}\cdot\frac{(\delta+\lambda)}{r+\lambda}\cdot Q^{\epsilon})^{-\beta_2}\frac{C}{r+\lambda}]$

$(1-\tau)S[(-\beta_2+1)(b+C)^{-\beta_2}(\frac{\beta_2}{\beta_2-1}\cdot\frac{(\delta+\lambda)}{r+\lambda}\cdot Q^{\epsilon})\frac{Q^{-\epsilon}}{\delta+\lambda} + \beta_2(b+C)^{-\beta_2-1}\frac{C}{r+\lambda}]$

$\frac{1-\tau}{r+\lambda}S\cdot[(b+C)^{-\beta_2}(-\beta_2) + C\beta_2(b+C)^{-\beta_2-1}]$

$(b+C)^{-\beta_2}\frac{1-\tau}{r+\lambda}S\cdot[-\beta_2 + C\beta_2(b+C)^{-1}]$

Then putting back in the negative alpha and rearranging:

$$-\alpha\beta_2(b+C)^{-\beta_2}\frac{1-\tau}{r+\lambda}S\cdot[-1+C(b+C)^{-1}] \tag{62}$$

Setting the sum of all three to zero:

$\frac{\tau}{r+\lambda} + \beta_2(b+C)^{-\beta_2-1}\frac{\tau\cdot b}{r+\lambda}S - (b+C)^{-\beta_2}\frac{\tau}{r+\lambda}S - \alpha\beta_2(b+C)^{-\beta_2}\frac{1-\tau}{r+\lambda}S\cdot[-1+C(b+C)^{-1}] = 0$

$\underline{\tau} + \beta_2(b+C)^{-\beta_2-1}\underline{\tau\cdot b}S - (b+C)^{-\beta_2}\underline{\tau}S - \alpha\beta_2(b+C)^{-\beta_2}\underline{1-\tau}S\cdot[-1+C(b+C)^{-1}] = 0$

Dividing by S:

$\frac{\tau}{S} + \beta_2(b+C)^{-\beta_2-1}\frac{\tau \cdot b}{} - (b+C)^{-\beta_2}\frac{\tau}{} - \alpha\beta_2(b+C)^{-\beta_2}\frac{1-\tau}{} \cdot [-1 + C(b+C)^{-1}] = 0$

Multiplying by b+C to the B2:

$\frac{\tau}{S}(b+C)^{\beta_2} + \beta_2(b+C)^{-1}\frac{\tau \cdot b}{} - \frac{\tau}{} - \alpha\beta_2\frac{1-\tau}{} \cdot [-1 + C(b+C)^{-1}] = 0$

Multiplying by b+C:

$\frac{\tau}{S}(b+C)^{\beta_2+1} + \beta_2\tau \cdot b - \tau(b+C) - \alpha\beta_2(1-\tau) \cdot [-b] = 0$

$\frac{\tau}{S}(b+C)^{\beta_2+1} + \beta_2\tau \cdot b - \tau(b+C) + \alpha\beta_2 b(1-\tau) = 0$

If C=0..

$\frac{\tau}{S}(b)^{\beta_2+1} + \beta_2\tau b - \tau b + \alpha\beta_2 b(1-\tau) = 0$

Divide by b...

$\frac{\tau}{S}(b)^{\beta_2} + \beta_2\tau - \tau + \alpha\beta_2(1-\tau) = 0$

$\frac{\tau}{S}(b)^{\beta_2} = -\beta_2\tau + \tau - \alpha\beta_2(1-\tau)$

$(b)^{\beta_2} = (-\beta_2 + 1 - \alpha\beta_2(\frac{1-\tau}{\tau}))S$

$S = \left(\frac{X}{\frac{\beta_2}{\beta_2-1}\cdot\frac{\cdot(\delta+\lambda)}{r+\lambda}\cdot Q^{\epsilon}}\right)^{\beta_2}$

$$\tau S^{-1}(b+C)^{\beta_2+1} = b(-\tau\beta_2 + \tau - \alpha(1-\tau)\beta_2) + \tau C \tag{63}$$

Appendix 4: Entry threshold derivation

The unknown variables are X_H, K, and Q. (but Q will be determined in industry equilibrium). So next I are going to solve for X_H and K as functions of the rest of the variables.

First let's solve for K using the value matching:

$V_0(X_H, Q) = K \cdot (X_H Q^{-\epsilon})^{\beta_1} = V_L(X_H, Q, b) - I$

This implies that:

$$K = (X_H Q^{-\epsilon})^{-\beta_1}[V_L(X_H, Q, b) - I] \tag{64}$$

Now let's move on to the smooth pasting condition.

Let's compute the derivatives:

1. $V_0'(X_H, Q) = \beta_1 K \cdot (X_H^{\beta_1 - 1} \cdot Q^{-\epsilon\beta_1})$

In the second one I could the product rule for the middle term and implicitly derive $\frac{db}{dX}$ or assume that firms cannot adjust leverage after the initial X draw, so that this derivative is 0. In order to take the derivative with respect to X_H, I will need to implicitly differentiate the equation defining b since b is a function of X. I will leave this term until the end though.

2. $V_L'(X_H, Q, b) = U'(X_H, Q) + \frac{\tau}{r+\lambda}(1-q)\frac{db}{dX} + \frac{\tau \cdot b}{r+\lambda}\frac{d(1-q)}{dX} - \alpha \cdot U(X_D, Q) \cdot \frac{dq}{dX}$

Derive the first term:

$(1-\tau)[\frac{Q^{-\epsilon}}{\delta+\lambda} + \beta_2[\frac{C}{r+\lambda} - \frac{X_L Q^{-\epsilon}}{\delta+\lambda}]\left(\frac{X_H^{\beta_2-1}}{X_L^{\beta_2}}\right)]$
Expanding the last two terms:

$\frac{\tau \cdot b}{r+\lambda}\frac{d(1-q)}{dX} - \alpha \cdot U(X_D, Q) \cdot \frac{dq}{dX}$

$= \frac{\tau \cdot b}{r+\lambda}(-\beta_2\left(\frac{X_H^{\beta_2-1}}{X_D^{\beta_2}}\right) - \alpha \cdot U(X_D, Q) \cdot \beta_2\left(\frac{X_H^{\beta_2-1}}{X_D^{\beta_2}}\right)$

$= -\beta_2\left(\frac{X_H^{\beta_2-1}}{X_D^{\beta_2}}\right)(\frac{\tau \cdot b}{r+\lambda} + \alpha \cdot U(X_D, Q))$

So in total I have
$V_L'(X_H, Q, b) = (1-\tau)[\frac{Q^{-\epsilon}}{\delta+\lambda} + \beta_2[\frac{C}{r+\lambda} - \frac{X_L Q^{-\epsilon}}{\delta+\lambda}]\left(\frac{X_H^{\beta_2-1}}{X_L^{\beta_2}}\right)] - \beta_2\left(\frac{X_H^{\beta_2-1}}{X_D^{\beta_2}}\right)(\frac{\tau \cdot b}{r+\lambda} + \alpha \cdot U(X_D, Q))$
Now I are ready to plug these into the value matching and smooth pasting conditions for entry.

$\beta_1 K \cdot (X_H^{\beta_1-1} \cdot Q^{-\epsilon\beta_1}) = (1-\tau)[\frac{Q^{-\epsilon}}{\delta+\lambda} + \beta_2[\frac{C}{r+\lambda} - \frac{X_L Q^{-\epsilon}}{\delta+\lambda}]\left(\frac{X_H^{\beta_2-1}}{X_L^{\beta_2}}\right)] - \beta_2\left(\frac{X_H^{\beta_2-1}}{X_D^{\beta_2}}\right)(\frac{\tau \cdot b}{r+\lambda} + \alpha \cdot U(X_D, Q))$
Replacing for K, I have:

$\beta_1[V_L(X_H, Q, b) - I] \cdot (X_H^{-1}) = (1-\tau)[\frac{Q^{-\epsilon}}{\delta+\lambda} + \beta_2[\frac{C}{r+\lambda} - \frac{X_L Q^{-\epsilon}}{\delta+\lambda}]\left(\frac{X_H^{\beta_2-1}}{X_L^{\beta_2}}\right)] - \beta_2\left(\frac{X_H^{\beta_2-1}}{X_D^{\beta_2}}\right)(\frac{\tau \cdot b}{r+\lambda} + \alpha \cdot U(X_D, Q))$

Multiplying by Xh:

$$\beta_1[V_L(X_H,Q,b)-I] = (1-\tau)[\tfrac{X_H Q^{-\epsilon}}{\delta+\lambda}+\beta_2[\tfrac{C}{r+\lambda}-\tfrac{X_L Q^{-\epsilon}}{\delta+\lambda}]\left(\frac{X_H^{\beta_2}}{X_L^{\beta_2}}\right)]-\beta_2\left(\frac{X_H^{\beta_2}}{X_D^{\beta_2}}\right)(\tfrac{\tau\cdot b}{r+\lambda}+\alpha\cdot U(X_D,Q))$$

Now I need to add back in term with the derivative of b with respect to X, which is:

$$+\tfrac{\tau}{r+\lambda}(1-q)\tfrac{db}{dX}$$

So I have in total:

$$\beta_1[V_L(X_H,Q,b)-I] = (1-\tau)[\tfrac{X_H Q^{-\epsilon}}{\delta+\lambda}+\beta_2[\tfrac{C}{r+\lambda}-\tfrac{X_L Q^{-\epsilon}}{\delta+\lambda}]\left(\frac{X_H^{\beta_2}}{X_L^{\beta_2}}\right)]-\beta_2\left(\frac{X_H^{\beta_2}}{X_D^{\beta_2}}\right)(\tfrac{\tau\cdot b}{r+\lambda}+\alpha\cdot U(X_D,Q))+X_H\cdot \tfrac{\tau}{r+\lambda}(1-q)\tfrac{db}{dX}$$

$\frac{db}{dX} = \frac{\beta_2 X^{-\beta_2-1}(b+C)^{\beta_2}R}{b^{-1}+R\cdot X^{-\beta_2}(b+C)^{\beta_2}[\beta_2(b+C)^{-1}-b^{-1}]}$ where $R = \left(\frac{\beta_2}{\beta_2-1}\cdot\frac{\delta+\lambda}{r+\lambda}\cdot Q^{\epsilon}\right)^{\beta_2}$

Appendix 5: Stationary distribution

In this appendix I derive the stationary distribution of firms in detail. From (14), I have the balance condition, that at each segment number of arriving firms=number of departing:

$\phi(x)dh = Ndt\cdot g(exp(x))dh + p(1-\lambda dt)\phi(x-dh)dh + q(1-\lambda dt)\phi(x+dh)dh$

Canceling the common dh factor and expanding the $\phi(x+dh)$ and $\phi(x-dh)$ expressions via Taylor expansions, I get:

$$.5\sigma^2\phi''(x) - (\alpha-.5\sigma^2)\phi'(x) - \lambda\phi(x) + Ng(exp(x)) = 0 \tag{65}$$

The general solution to this equation is of the following form:

$$\phi(x) = C_1 exp(\gamma_1 x) + C_2 exp(\gamma_2 x) + \phi_0(x) \tag{66}$$

The first two terms are the solution to the homogeneous portion and the last term is the particular solution to the full equation. Since I assumed the initial distribution, $g(X)$ is uniform over $(0,\hat{X})$, then $x = ln(X)$ follows the exponential distribution over $(-\infty,\hat{x})$, where $\hat{x} = ln(\hat{X})$, resulting in pdf of $exp(x-\hat{x})$. I can use this form to find $\phi_0(x)$ and can verify that $\phi_0(x) = \frac{N\cdot exp(x-\hat{x})}{-\sigma^2+\alpha+\lambda}$. To see this, first note that $\phi_0(x) = \phi_0'(x) = \phi_0''(x)$. Plugging in the derivatives of $\phi(x)$ into (23), $\phi_0(x)$ must satisfy the following:

$.5\sigma^2\phi_0''(x) - (\alpha-.5\sigma^2)\phi_0'(x) - \lambda\phi_0(x) = -N\cdot exp(x-\hat{x})$

It is clear that it does.

Note that this solution is only for the region that receives new firms, meaning $x \in [x_H, \hat{x}]$. The other regions follow the homogeneous part and have solutions that consist of the first two terms of (24). I therefore arrive at the piece-wise function for the full distribution:

$$\phi(x) = \begin{cases} C_1 exp[\gamma_1 x] + C_2 exp[\gamma_2 x] & x \in [x_L, x_H] \\ C_3 exp[\gamma_1 x] + C_4 exp[\gamma_2 x] + \phi_0(x) & x \in [x_H, \hat{x}] \\ C_5 exp[\gamma_1 x] + C_6 exp[\gamma_2 x] & x \in [\hat{x}, \infty) \end{cases}$$

C_5 must be 0. Otherwise, since γ_1 is positive, the distribution will explode as $x \to \infty$.
I also must have that $\phi(x_L) = 0$, since the distribution gets no incomers from the left.
I also must have value matching and smooth pasting at x_H and $\hat{x}$.
This gives us the 5 conditions I need, in order to solve for the 5 constants.

To make things less cluttered, let's let $x1 = exp[\gamma_1 x_H]$, $x2 = exp[\gamma_2 x_H]$, $x3 = exp[\gamma_1 \hat{x}]$, $x4 = exp[\gamma_2 \hat{x}]$, $x5 = exp[\gamma_1 x_L]$, and $x6 = exp[\gamma_2 x_L]$.

So the equations are:
1. $C_1 x1 + C_2 x2 = C_3 x1 + C_4 x2 + \phi_0(x_H)$
2. $\gamma_1 C_1 x1 + \gamma_2 C_2 x2 = \gamma_1 C_3 x1 + \gamma_2 C_4 x2 + \phi_0'(x_H)$
3. $C_6 x4 = C_3 x3 + C_4 x4 + \phi_0(\hat{x})$
4. $\gamma_2 C_6 x4 = \gamma_1 C_3 x3 + \gamma_2 C_4 x4 + \phi_0'(\hat{x})$
5. $C_1 x5 + C_2 x6 = 0$

Inserting equation 3 to the left side of equation 4, I get:
$\gamma_2(C_3 x3 + C_4 x4 + \phi_0(\hat{x})) = \gamma_1 C_3 x3 + \gamma_2 C_4 x4 + \phi_0'(\hat{x})$

Simplifying,

$C_3 = \frac{-\gamma_2 \phi_0(\hat{x}) + \phi_0'(\hat{x})}{x3(\gamma_2 - \gamma_1)}$

Using equation 5, I get C_2 in terms of C_1:
$C_2 = \frac{-C_1 x5}{x6}$

Subtracting the second term from both sides of equations 1 and 2, and then inserting equation 1 to the left side of equation 2, I get:
$C_2 x2 = C_3 x1 + C_4 x2 + \phi_0(x_H) - C_1 x1$

$\gamma_2 C_2 x2 = \gamma_1 C_3 x1 + \gamma_2 C_4 x2 + \phi_0'(x_H) - \gamma_1 C_1 x1$
So, $\gamma_2(C_3 x1 + C_4 x2 + \phi_0(x_H) - C_1 x1) = \gamma_1 C_3 x1 + \gamma_2 C_4 x2 + \phi_0'(x_H) - \gamma_1 C_1 x1$

I see that the C_4 terms cancel out:
$\gamma_2(C_3 x1 + \phi_0(x_H) - C_1 x1) = \gamma_1 C_3 x1 + \phi_0'(x_H) - \gamma_1 C_1 x1$

So now put C_1 in terms of C_3:
$-\gamma_2 C_1 x1 + \gamma_1 C_1 x1 = \gamma_1 C_3 x1 + \phi_0'(x_H) - \gamma_2 C_3 x1 - \gamma_2 \phi_0(x_H)$

$C_1 = \frac{C_3 x1(\gamma_1 - \gamma_2) + \phi_0'(x_H) - \gamma_2 \phi_0(x_H)}{x1(\gamma_1 - \gamma_2)}$

Now I can use equation 1 to get C_4:
$C_4 = [C_1 x1 + C_2 x2 - C_3 x1 - \phi_0(x_H)]/x2$

Now I can use equation 3 to get C_6:
$C_6 = [C_3 x3 + C_4 x4 + \phi_0(\hat{x})]/x4$