Tariff Rate Uncertainty and the Structure of Supply Chains*

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Abstract

We model how changes in trade policy affect firms' choice of procurement system. We show that a reduction in the probability of a trade war can foster the adoption of "Japanese"-style procurement practices, in which domestic buyers ensure the provision of high-quality inputs from foreign suppliers via long-term, just-in-time relationships. Empirically, we demonstrate that a change in U.S. trade policy that eliminated the possibility of substantial increases in U.S. tariffs on Chinese goods coincides with a shift towards "Japanese" procurement. Quantitative simulations suggest that this shift led to substantial U.S. welfare gains. (JEL F13, F14, F15, F23) (Keywords: Supply Chain, Uncertainty, Trade War, Procurement)

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1 Introduction

Motivated by the success of Japanese manufacturers such as Toyota, many firms around the world have introduced "Japanese"-style procurement practices in an effort to enhance operational efficiency.[1] A key feature of these systems – separate from the much-studied just-in-time inventory management – is the presence of long-term relationships between buyers and sellers (Liker and Choi (2004)).[2] Understanding these relationships has become increasingly important given the increasingly global reach of supply chains (Baldwin and Lopez-Gonzalez (2015)), as well as the consideration of more restrictive trade policies by politicans in many developed countries, including the United States.[3] Indeed, if buyers and sellers are located in different countries, the possibility of a trade war can inhibit foreign sellers from entering into the sort of long-term relationships with domestic buyers that characterize the "Japanese" system.[4] This disincentive can adversely affect firm performance and welfare in several ways. For example, the prospect that trade policy may break up a buyer-seller relationship might raise buyers' costs by forcing them to hold higher levels of inventory.

This paper examines the role of trade policy in firms' selection of procurement systems both theoretically and empirically. In the first part of the paper, we develop a model in which buyers select one of two stylized procurement systems analyzed in Taylor and Wiggins (1997) as a way of solving a quality control problem. Under the "Japanese" system, buyers motivate sellers to maintain product quality by committing to purchases at a price above sellers' costs in a long-term relationship. The opposing "American" system, by contrast, has buyers choosing the lowest-cost seller for each order via competitive bidding, and using costly inspection to deter cheaters from shipping low quality, with buyers unattached to a particular seller. We demonstrate that changes in sellers' assessment of the probability of a trade war can induce firms to

[1]This movement is documented in a series of studies. See, for example, O'Neal (1989), Heide and John (1990), Lyons, Krachenberg, and Henke Jr. (1990), Dyer and Ouchi (1993), Han, Wilson, and Dant (1993), Helper and Sako (1995) and Liker and Choi (2004).

[2]More broadely, "Japanese"-style buyer-seller relationships are also characterized by joint learning and information sharing, though we do not examine these elements in this paper.

[3]In the U.S., analysts have noted the effects on supply chains of potential withdrawal from NAFTA (Wall Street Journal 2017), as well as the actual withdrawal from the Trans-Pacific Partnership (Mauldin 2017). Similar concerns have been raised regarding the effect of the United Kingdom's exit from the European Union (Campbell and Pooler 2017).

[4]A new but growing literature uses the detailed importer-exporter information in the U.S. trade data to observe the structure of supply chains and buyer-seller relationships, including Monarch (2015), Boehm, Flaaen, and Pandalai-Nayar (2015), Monarch and Schmidt-Eisenlohr (2015) and Heise (2015).

switch between the American and Japanese systems. In the second part of the paper we first show that our model captures key features of transaction-level U.S. import data, and then demonstrate that a change in U.S. trade policy that eliminated the possibility of substantial tariff increases on Chinese imports coincides with a relative shift towards Japanese-style procurement between U.S. buyers and Chinese sellers. In the final part of the paper we combine the results of the empirical analysis with numerical simulations of an estimated multi-country model to explore potential welfare gains associated with the change in U.S. policy.

Our theoretical analysis is based on the framework introduced by Taylor and Wiggins (1997), where buyers face exogenous demand and choose a procurement system to minimize costs subject to incentive constraints. Taylor and Wiggins (1997) demonstrate that shipments between seller and buyer are optimally smaller and more frequent – i.e., more "just-in-time" – under the Japanese system. Here, we embed the Taylor and Wiggins (1997) setup in a more general framework in which demand for varieties is determined in equilibrium. We first show that, given the contractual frictions imposed by the model, the buyers face increasing returns to scale. We therefore assume that the buyer's market is "contestable" (Baumol, Panzar, and Willig (1982)), a natural extension to price competition in the presence of economies of scale (Tirole (1988)), and show that in equilibrium a single buyer serves the market for each variety. We then theoretically examine the characteristics of transactions under the two systems and the equilibrium response to a change in the probability of trade peace with another country.

We show that for a given demand, shipments under the Japanese system are smaller, more frequent, and exhibit higher unit values than under the American system due to the incentive premium paid. We then demonstrate that the higher are sellers' (exogenous) beliefs about the probability of trade peace with another country, the more likely they are to enter into Japanese-style procurement relationships with buyers from that country. The intuition for this result is straightforward: the higher the belief about the probability of trade peace, the greater the seller's confidence that a long-term relationship with a particular buyer can be sustained. This increased confidence lengthens the time horizon over which the seller expects to collect a premium over their costs from exporting their intermediate good to the buyer, driving down the premium needed to incentivize quality and thereby the relative cost of the Japanese system compared to the American system. Importantly, this reduction in the relative cost of the Japanese system implies that an increase in the probability of trade peace can lead firms to switch from the American to the Japanese system.

In our empirical analysis, we examine some of the fundamental features of our model using transaction-level U.S. import data. Through the lens of the model, we classify importers as using either Japanese- or American-style procurement based on the number of foreign suppliers from which they purchase goods within a product-country bin. We classify a buyer's procurment system as American or Japanese based on the number of suppliers used to source a specific production. Many suppliers are interpreted as evidence of American-style procurement, while purchases from a small number or even a single supplier are deemed evidence of a Japanese-style relationship. We then show that to procure a given quantity over a given time horizon, importers using more suppliers and hence classified as American rely on larger, less frequent shipments from each supplier, at lower prices and overall shorter relationships, as implied by the model. We also demonstrate that products classified by Rauch (1999) as differentiated exhibit smaller, more frequent shipments and longer relationships than products which have reference prices or which are traded on organized exchanges. These findings accord well with the idea that differentiated products are more costly to inspect and are therefore more likely to be traded under the Japanese system. To our knowledge, these results provide the first systematic evidence supporting the key insights in Taylor and Wiggins (1997).

Next, we consider the model's implication that firms will switch procurement systems following a shift in the probability of trade peace. We examine this implication-through the lens of the U.S. extension of Permanent Normal Trade Relations (PNTR) to China in October 2000, which eliminated the annual threat of a sudden spike in U.S. tariffs on imports from China. Following Pierce and Schott (2016), we measure the exposure of a product to this trade liberalization as the magnitude of the potential jump in the tariff rate that could have occurred before the change in policy, which varies substantially across products. Our triple difference-in-differences specification asks whether U.S.-China transactions within importer-exporter-product bins change after the policy is implemented (first difference) for bins involving imports from China relative to other countries (second difference) and for products with greater relative to lesser exposure (third difference).[5] In line with the model's prediction for a switch

[5]In our model, seller and buyer trade a single product, so the probability of a trade war and the probability the seller-buyer relationship ends are the same. Our empirical analysis, on the other hand, examines firms trading a wide range of products subject to varying increases in tariffs in the event of

of systems , we find that U.S.-Chinese shipments of more-exposed products become relatively smaller, relatively more frequent, and relatively higher priced – that is, more "Japanese"-style – after the change in policy. Coefficient estimates suggest that a one standard deviation increase in the *ex ante* potential jump in tariff rates is associated with a relative decline in average shipment quantity of 13 percent and an increase in average shipment price of 4 percent.

In the final part of the paper we embed our framework into the multi-country model of Eaton and Kortum (2002). Our setup is an extension of the original framework allowing for increasing returns to scale, which are micro-founded by the explicit modelling of a procurement system. The model determines comparative advantage, and hence trading patterns, based on cross-country productivity differences as in Eaton and Kortum (2002), but also based on the bilateral probability of trade peace, which affects procurement costs by changing the costs of using the Japanese system. We present quantitative simulations of the model that incorporate changes in shipment patterns highlighted in our empirical analysis. These simulations reveal that the change in procurement patterns induced by the policy change increases U.S. imports from China by approximately 20 percent relative to previous levels, partly at the expense of other trading partners that were not subject to the policy change. The change in procurement patterns also has implications for U.S. welfare, which increases by 0.2 percent via a decline in final goods prices. This analysis suggests that changes in trade policy can have a meaningful impact on trade flows and welfare by inducing firms to re-optimize with respect to procurement.

Our model isolates the mechanism by which trade policy affects trade flows from the generic productivity parameter in Eaton and Kortum (2002), which could be considered a reduced-form parameter capturing many factors that differ across countries, and points out that welfare-enhancing policies might include making the probability of a trade war less likely. Moreover, the model highlights a potential source of welfare gains arising from the expansion of U.S.-China trade – the formation of welfare-enhancing long-term supply chain relationships. While we develop the model in the context of changes in the probability of trade peace, the underlying mechanism applies more broadly towards any policies that might undermine sellers' beliefs about the viability of establishing long-term relationships with buyers, e.g., uncertainty over the arrival of shipments due to corruption or weather at ports.

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a failed annual renewal prior to PNTR.

This paper makes contributions to several fields. The model we develop is to our knowledge the first to link trade policy to the choice of procurement systems, and provides an alternate perspective on the large literature examining contractual frictions in international trade.[6] Indeed, one solution to the problem of hold-up in the decision to outsource may be relationship formation (Kukharskyy and Pflüger (2010)), i.e., the sharing of long-term gains in a repeated game. Here, we examine how long-term, "Japanese" relationships can overcome frictions associated with guaranteeing the provision of high-quality inputs. One attractive feature of our approach is that it yields predictions regarding shipment patterns that can be tested using transaction-level trade data.[7]

More broadly, our paper contributes to research examining the behavior of importers (e.g., Blaum, Lelarge, and Peters (2015)), the implications of trade wars (e.g., Ossa (2014)), information frictions in international trade (e.g., Cristea (2011)), trade policy uncertainty (e.g., Handley and Limão (2013), Handley (2014)), importer-exporter relationships in international trade (Heise (2015), Monarch and Schmidt-Eisenlohr (2015)), and the impact of supply-chain disruptions on output (e.g., Boehm, Flaaen, and Pandalai-Nayar (2015)).

The remainder of this paper proceeds as follows. Section 2 outlines our theoretical model. Section 3 describes the data and presents our empirical analysis. Section 5 contains our quantitative simulations. Section 6 concludes. An online appendix contains additional results.

2 Theoretical Model

Incomplete contracts, information asymmetries and contract enforcement are common problems when domestic buyers procure products from foreign suppliers. Existing models focus on firm integration to solve these problems (Antràs (2003, 2005); Antràs and Helpman (2008); Feenstra and Hanson (2005); Fisman and Wang (2010); Grossman and Helpman (2004); Spencer (2005)). Here, we build on Taylor and Wiggins (1997),

[6]See, for example, the survey by Antràs and Helpman (2008). Procurement within countries is a subject of considerable research in the industrial organization literature. See, for example, Tadelis and Zettelmeyer (2015), Cicala (2015) and Bajari et al. (2014).

[7]Our model also contrasts with existing models of heterogeneous firms and trade, in which producers balance fixed and variable costs in determining whether to export or engage in foreign direct investment (e.g., Melitz 2003, Bustos 2011). Here, as in Taylor and Wiggins (1997), however, the fixed and variable costs are endogenous to firms' choice of a procurement system.

who distinguish "American" and "Japanese" procurement systems to solve contractual and information frictions when vertical integration is not an option, perhaps due to legal barriers. Under the American system, buyers use competitive bidding to select the lowest-cost supplier for each shipment, and use the threat of inspection to deter provision of low quality goods. Under the Japanese system, buyers induce honesty by paying incentive premia in long-term relationships. In constrast to Taylor and Wiggins (1997), we allow procurement costs to be affected by the probability of trade peace, and determine demand in equilibrium (as opposed to assuming exogenous demand). These features allow us analyze the effect of a change in the probability of trade peace on trade flows and welfare.

We show that buyers' average costs are downward sloping, and therefore assume that they compete for downstream consumers in a contestable market (Baumol, Panzar, and Willig (1982)), a natural extension to price competition in the presence of economies of scale (Tirole (1988)). In equilibrium, a single buying firm procures and distributes the product using the cost minimizing procurement system, and the ability to sustain a Japanese relationship depends on the stability of trade policy. We provide several analytical results related to trade policy that can be used to distinguish the two systems empirically, and consider these predictions empirically in the next section. We then evaluate contractual frictions in a numerical model based on an extension of Eaton and Kortum (2002) that allows for returns to scale and a choice of procurement system.

2.1 The Contracting Problem

2.1.1 The Seller's Problem

There is a continuum of homogeneous sellers able to produce the same good located in a single country.[8] To complete a production run sellers hire labor l at wage $w = 1$ to produce and deliver output $x = \frac{\Upsilon}{\theta} l$, where Υ is a seller's productivity and θ represents the seller's product's level of quality. The unit input requirement, $\frac{\theta}{\Upsilon}$, allows for variation in quality, giving rise to a "quality control" problem.[9] Sellers choose between discrete quality levels, $\theta \in \left\{\underline{\theta}, \overline{\theta}\right\}$, where lower quality is cheaper to produce. To complete the shipment, the seller absorbs f units of labor for per-shipment specific

[8] We extend the model to multiple products and sellers in multiple countries in Section 5.1 below.
[9] See, for example, "Poorly Made", The Economist, May 14th, 2009.

logistics services, including transport costs.[10] The sellers' total cost for each production and delivery cycle are therefore $x\frac{\theta}{\Upsilon}+f$.

2.1.2 The Buyer's Procurement Choices

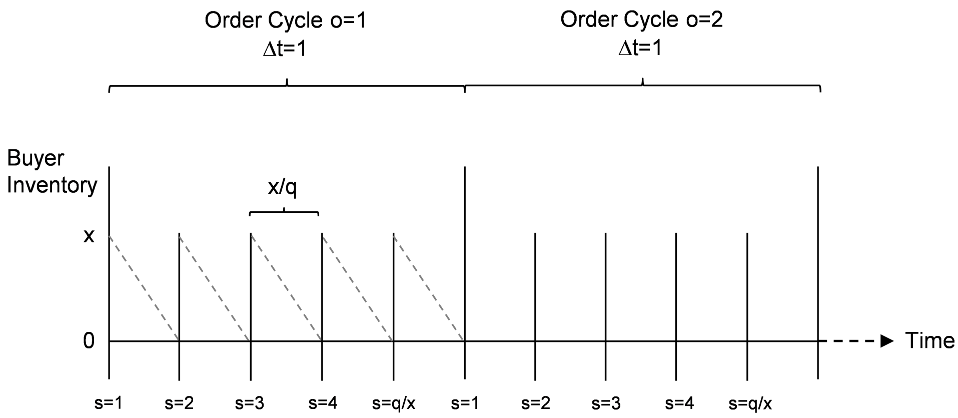
There exist multiple homogeneous buyers that are willing to procure the seller's output and distribute it downstream in the consumer market. These buyers compete in a contestable market, described in greater detail below. Let t denote continuous time and consider time periods $\Delta t = \int_0^1 1dt = 1$, e.g., 1 year. Conditional on desired quality, $\overline{\theta}$, let consumer demand arrive continuously. To supply the consumer market over one time period, a buyer procures total quantity, q, in a series of discrete, equally sized, symmetric shipments of size x. We take q as fixed in this section, but solve for it in equilibrium in Section 2.3. Consequently, there are q/x shipments during each period. Figure 1 summarizes the shipment and consumption pattern visually. If quality is less than desirable, no downstream consumer demand arrives for the product and buyers must dispose of the obsolete shipment without recompense. To avoid these losses, the buyer seeks to ensure the provision of high-quality inputs using either an "American" (A) or a "Japanese" (J) procurement system. In the American (A) system, buyers pay fixed cost m_A to inspect each shipment's quality before delivery. We assume inspections reveal quality with certainty.[11] Therefore, if buyers inspect, sellers cannot gain by cheating on product quality. Consequently, buyers know that inspections guarantee product quality. We assume that buyers have all the bargaining power. As a result, given an order of size x_A placed with a seller, the buyer sets the per shipment price $v_A(x_A, \overline{\theta})/x_A$ to allow the seller to break even and participate, where

$$v_A(x_A, \overline{\theta}) = f + \frac{\overline{\theta}}{\Upsilon} x_A. \tag{1}$$

Due to the fixed cost, the buyers' average procurement costs are decreasing in order size, and therefore each buyer optimally places each order with a single seller. Since the sellers are homogeneous and all willing to supply at the same price, we assume

[10]While a large literature within international trade models the cost of shipping between origin and destination as "iceberg", i.e., a fractional loss of the shipped good which rises with distance, recent evidence supports per-unit and per-shipment specific delivery costs (Hummels and Skiba (2004); Martin (2012);Kropf and Sauré (2014); Hornok and Koren (2015b); Hornok and Koren (2015a)) .

[11]Taylor and Wiggins (1997) allow for a more general inspection pattern and show that optimal inspection frequency under the American system is a function of shipment size and quality. This does not affect our conclusions related to per-shipment costs.



Notes: The total quantity shipped over an order cycle is q. Order cycles repeat indefinitely and are indexed by o={1,2,…}. There are s={1,2,..q/x} shipments during an order cycle, each arriving every x/q units of time apart.

Figure 1: Timing

that for a given buyer the winning seller is chosen randomly for each order. Inclusive of inspection costs, the buyer's total procurement expense equals $v_A(x_A, \theta) + m_A$. The form of this procurement cost is similar to those appearing elsewhere in the literature (Kropf and Sauré (2014); Hornok and Koren (2015b); Hornok and Koren (2015a)), where exogenous per-shipment fees such as f and m_A capture administrative barriers.

Japanese (J) procurement motivates the production of high quality by the promise of a long-term relationship with a single seller rather than inspection. A seller chooses to ship high quality if a long-run relationship with the buyer is of sufficient value, and a contribution of this paper is to show how this value depends upon the stability of trade policy between seller and buyer countries. We assume trade policy shocks that break buyer-seller relationships, e.g., an escalation of the tariff on the product to a prohibitive level, arrive at a constant rate, ρ.[12] In that case, relationships break before time t with probability $F(t) = 1 - exp(-\rho t)$, implying survival over a shipment cycle with probability $e^{-\frac{\rho x}{q}}$.[13] We note that while our focus is on trade policy, there are many other shocks which might have similar effects.

For our purposes, $e^{-\frac{\rho x}{q}} < 1$ implies that firms are uncertain about whether future trade policy facilitates relationships. For a given shipping cycle $\frac{x_J}{q}$, a greater arrival

[12]Ossa (2014), for example, estimates that the optimal tariffs countries might set in the event of a trade war are substantial, averaging 63 percent worldwide.

[13]For proof see Wooldridge (2002), page 688.

rate of trade wars, ρ, increases the separation probability. Let r be the per-period interest rate and $v_J(x_J, \theta)$ be the payment the buyer sets under the Japanese system for each shipment. The expected discounted value of the relationship over all future shipment cycles is then $\frac{v_J(x_J,\bar{\theta})}{1-e^{-(r+\rho)x_s/q}}$.[14] Note that here, in contrast to the American system, a buyer procures each order from the same seller.

To guarantee desired quality, the buyer must set a per-shipment payment such that the seller's net present value of the continued relationship exceeds the one-time profit from cheating by supplying inferior quality,

$$\frac{v_J(x_J, \bar{\theta}) - f - \frac{\bar{\theta}}{\Upsilon} x_J}{1 - e^{-(r+\rho)x_s/q}} \geq v_J(x_J, \bar{\theta}) - f - \frac{\underline{\theta}}{\Upsilon} x_J. \tag{2}$$

In this expression, we assume that if the seller provides low quality, the buyer does not find out about it until after the shipment is received and the payment is made, and that the relationship is broken forever. Moreover, we assume that a seller delivering low quality is excluded from the market forever. Here, too, we assume buyers own all the bargaining power. Solving 2, buyers under the Japanese system set the per-shipment price to be

$$v_J(x_J, \bar{\theta}) = f + \bar{\theta}\frac{1}{\Upsilon} x_J + \left[e^{(r+\rho)x_J/q} - 1\right] (\bar{\theta} - \underline{\theta}) \frac{1}{\Upsilon} x_J. \tag{3}$$

In the Japanese system buyers pay the per-unit premium $\left[e^{(r+\rho)x_J/q} - 1\right] (\bar{\theta} - \underline{\theta}) \frac{1}{\Upsilon}$ to induce the seller to provide high quality. More stable trade relationships (i.e., lower separation rates) and smaller shipments sent more frequently (which increase the present discounted value of payments)reduce the premium necessary to guarantee desired quality.[15] As a result, compared to a setting without incentive problems (e.g., an integrated firm), Japanese procurement has higher variable costs while American

[14] Tthe discount rate over a shipping cycle with associated continuous discount factor is $\lim_{N \to \infty} \left(\frac{1}{1+\frac{rx}{q}/N}\right)^N = e^{-\frac{rx}{q}}$. The model considers trade in a single product. An alternate interpretation of ρ that brings the model closer to our data analysis below is that it reflects both the probability of a trade war (which is the same for all products) and the subsequent rise in tariffs (which might vary across products) for the particular good being traded. The probability of breakup is rising in the latter.

[15] An alternative approach to incorporating trade policy uncertainty would be to multiply the discount factor by an exogenous probability of trade peace $(1-\rho)$. However, a drawback of that approach is that the probability of relationship separation over a given time period is dependent of the number of shipments made. In our forumlation, the likelihood of separation is independent of shipment freqency.

procurement system has higher fixed costs.

Buyers choose between the American and Japanese system by comparing long-term expected revenues and costs. We assume that a trade war causes buyers to exit irrespective of the system they choose, as they lose access to the suppliers of their good.[16] At a given market price p, long-term expected profits in the two procurement systems are given by

$$\pi_s^b = \left[\int_0^{x_S/q} e^{-rt} pq\, dt - v_S(x_S, \bar{\theta}) - m_S\right] / \left[1 - e^{-(r+\rho)x_S/q}\right] \text{ s}\in\text{J,A} \tag{4}$$

where discounted revenues at the beginning of each shipment cycle are $\int_0^{x_s/q} e^{-rt} pq\, dt$ and $m_J = 0$.

2.2 Market Equilibrium and Optimal Procurement Choice

Since buyers are homogeneous and their market is characterized by free entry due to our assumption of contestable markets, discussed further in Section 2.3, profits are zero in equilibrium, and the market price must equal average procurement and distribution costs, $AC_s(x_s, q)$. At a higher price additional buyers could enter and capture the market while realizing a strictly positive profit. Setting profits equal to zero and solving for prices we obtain zero-profit conditions conditional on the procurement system,

$$p_s = AC_s(x_s, q) = \left(\frac{r}{q}\right) \frac{v_s(x_s, \bar{\theta}) + m_s}{[1 - e^{-rx_s/q}]} \text{ s}\in\text{J,A,} \tag{5}$$

where $m_J = 0$. Buyers choose a procurement pattern and procurement system to minimize average costs. Consequently, in equilibrium, each incumbent chooses a shipment size to minimize average procurement costs and chooses the optimal cost-minimizing procurement system. Taking first order conditions (FOC_s) and setting them to zero we obtain,

$$\frac{v_s'(x_s, \bar{\theta})}{1 - e^{-rx_s/q}} = \frac{\left[v_s(x_s, \bar{\theta}) + m_s\right] \frac{r}{q} e^{-rx_s/q}}{\left(1 - e^{-rx_s/q}\right)^2} \text{ s}\in\text{J,A.} \tag{6}$$

This expression implicitly determines shipment size, x_s^*. The left hand side represents the discounted value of higher costs associated with a small increase in order size. The

[16]In the model with multiple sellers discussed below, an alternate assumption is that buyers switch to a seller from another country in the event of a trade war. Given that buyer profits are zero in equilibrium, however, this assumption is equivalent to assuming that the buyer exits.

right hand side measures the savings from an increased discount factor due to spacing these larger orders further apart in time. Trading off these costs and benefits, the firm optimally procures x_s^* to minimize average expected purchasing costs. We show in Appendix A.1.1 that an interior solution to the first order condition is a unique cost minimizer for $0 < rx/q < 1$ under both procurement systems.

Conditional on procuring quantity q and parameter values, the buyer compares average procurement costs evaluated at the optimum, $AC_s\left(x_s^*, q\right)$, to determine the cost-minimizing procurement system. Implicit function techniques provide intuition for this comparison in the presence of nonlinearity. We focus our discussion on the impact of changes in inspection costs, the arrival rate of trade wars, and the endogenous incentive premium on the optimal procurement system.

Given this framework, we are able to examine the determinants of average shipping costs under both systems, We start by noting that with no variation in quality, i.e., for $\bar{\theta} - \underline{\theta} = 0$ and $m_A = 0$, there is no incentive problem and costs in both systems are identical. Compared to this benchmark case, differentiating equation (5) under the Japanese system with respect to $\underline{\theta}$ and ρ, respectively, and noting that, by the envelope theorem, the indirect effect coming from the resulting change in x_J is zero, we find that average procurement costs in the Japanese system increase with the range of potential qualities, $\bar{\theta} - \underline{\theta}$, and with the arrival rate of trade wars, ρ, due to the greater incentive premia they necessitate, $\frac{\partial AC\left(x_J^*\right)}{\partial \underline{\theta}} \leq 0$ and $\frac{\partial AC\left(x_J^*\right)}{\partial \rho} \geq 0$.[17] In the American system, differentiating (5) with respect to m shows that average costs increase with inspection costs m. Importantly, as $m \to \infty$, we have $AC_A\left(x_A^*, q\right) \to \infty$ because average costs grow without bound, $\frac{\partial AC_A\left(x_A^*\right)}{\partial m} = \frac{1}{1-e^{-\frac{rx}{q}}} > 1$. This result implies the following proposition.

Proposition 1. *For $\bar{\theta} - \underline{\theta} > 0$ and $\rho > 0$, there is always a value $m^* \in (0, \infty)$ such that average procurement costs in both systems are the same. This point is the cut-off at which the buyer switches systems: the American system is chosen for $m < m^*$, and the Japanese system is chosen for $m > m^*$.*

Proof. See Appendix A.1.3. □

This proposition highlights that changes in the arrival rate of trade wars may endogenously affect the choice of procurement system. Starting at a level of m slightly below m^*, a reduction in ρ lowers average costs under the Japanese system–while also

[17] See Appendix Section A.1.2 for further detail.

lowering m^* – and may cause the buyer to switch from the American to the Japanese system. This setting contrasts with existing studies of relational contracts in trade (e.g., Kamal and Tang (2015); Defever, Fischer, and Suedekum (2016)), where exogenous heterogeneity in discount rates determine relationship-based transactions.[18] Here, buyers endogenously determine the effective discount rate of rx_x/q by choosing the optimal procurement system and order size.

To map the choice of procurement system into observable trade flows, we first examine how order size, frequency, and unit values compare across the two systems holding q fixed. We discuss the determination of q in equilibrium below. We restrict our attention to a setting where buyers make a purchase at least once per period, $x^* \leq q$, and where discount rates are small, i.e., $0 < \frac{rx_s}{q} < 1$.

We first consider the impact of changes in ρ and m.

Proposition 2. *An increase in the probability of a trade war increases ρ, and therefore raises the unit value per shipment and reduces shipment size (i.e., raises shipment frequency) in the Japanese system. An increase in the inspection cost m raises shipment sizes, but reduces shipping frequencies and unit values in the American system.*

Proof. See Appendix A.1.4. □

While an increase in the separation rate ρ does not affect procurement patterns under the American system, under the Japanese procurement system it causes sellers to demand a greater premium to maintain quality. As a result, variable procurement costs increase and buyers re-optimize by lowering shipment sizes and raising shipping frequency. Given that fixed per-shipment costs are spread over smaller shipment sizes, the increase in ρ causes unit values to increase. On the other hand, an increase in the inspection cost m raises fixed per-shipment costs, and buyers under the American system re-optimize by decreasing shipping frequency and increasing per-shipment quantities. As a corollary, unit values must go down in the American system since fixed costs are spread over more units.

We can use these results to rank shipping frequencies and unit values across the two systems more generally. Consider the Japanese procurement system and suppose the quality range and inspection costs are both zero. In that case, the American and

[18] Defever, Fischer, and Suedekum (2016), for example, study a setup in which a buyer and a seller interact repeatedly and choose how much to invest into their relationship. They analyze different values of firms' discount rates and show that a cooperative equilibrium can only exist if both firms are sufficiently patient.

Japanese procurement systems are identical. As $\bar{\theta} - \underline{\theta}$ rises, variable shipment costs increase under the Japanese system, which raises the marginal benefit of increasing the shipping frequency and lowering shipment size. On the other hand, Proposition 2 shows that in the American system shipment size increases, and hence shipping frequency decreases, with inspection costs. For the case of $\bar{\theta} - \underline{\theta} > 0$ and $m \geq 0$, it must therefore be true that shipping frequencies are greater in the Japanese system and shipping sizes are greater in the American system. Furthermore, unit values are greater in the Japanese procurement system compared to American procurement system. This reasoning forms the basis of our second proposition.

Proposition 3. *Batch sizes in the American system are greater than in the Japanese system , $x_A^*> x_J^*$, and, unit values in the Japanese system are greater than in the American system, $v_J(x_J, \bar{\theta})/x_J > v_A(x_A, \bar{\theta})/x_A$.*

Proof. See Appendix A.1.5. □

We next examine the comparative statics with respect to q as a precursor to solving for q in the next section. We find that an increase in q raises shipment size and shipping frequency in both procurement systems. Intuitively, for a given fixed shipping frequency, firms must increase the batch size x in both systems to meet an increase in q. But by the first-order condition (equation 6) we know that firms trade-off variable procurement costs against fixed per-shipment costs. Therefore, as variable future expected procurement costs increase, buyers respond by spreading the larger quantities over more shipments. As a result, larger quantities purchased lead to greater shipment sizes, but also greater order frequencies and shorter shipment cycles. It follows that unit values in both procurement systems decrease, since fixed per shipment costs are spread over greater per-shipment quantities. In addition, under the Japanese system, an increase in the shipping frequency implies a lower premium to motivate desired quality. We summarize these reactions with the following proposition.

Proposition 4. *An increase in the procurement target q raises batch sizes x_s^* and the shipping frequency q/x_s^* in both systems, and, as a corollary, lowers unit values in both systems.*

Proof. See Appendix A.1.6.

□

2.3 Endogenous q Under a Contestable Market

We now consider the determination of q in equilibrium. We assume free entry by homogeneous buyers under a contestable market, a natural extension of Bertrand competition when firms' (i.e., potential buyers') costs exhibit economies of scale (Baumol, Panzar, and Willig (1982); Tirole (1988)). Two key features of a contestable market are that firms price optimally along average cost curves and that market prices are disciplined by entry if profits are positive. Our use of these features here is analogous to the assumption of perfect competition in benchmark models of international trade, e.g., Eaton and Kortum (2002).[19]

The trade-off between shipment size and frequency described in Proposition 4 has implications for the characteristics of the procurement technologies. As firms order larger batches in each shipping cycle (i.e., q rises), fixed per-shipment costs are spread over greater quantities.

In Lemma 1, we show that these scale effects dominate under both procurement systems, so that total average costs are downward sloping in q:

Lemma 1. *At the optimal order size x_s^*, both procurement systems provide economies of scale, i.e., $\frac{\partial AC(x_s^*,q)}{\partial q} < 0$. As corollary, a single buyer procures the product acting as the sole distributor. The second derivative of the average cost with respect to q is positive, $\frac{\partial^2 AC(x_s^*(q),q)}{\partial q^2} > 0$, and the average cost in both systems reaches a positive limit as $q \to \infty$.*

Proof. See Appendix A.1.7. □

Lemma 1 implies that average cost curves are convex and that a sustainable and feasible single-buyer equilibrium is characterized by zero profits, no incentive for entry or exit, and cleared markets. A demand curve that uniquely intersects the single buyer's optimized average cost curve from above determines a unique sustainable and feasible equilibrium, q^*. The buyer prices and supplies the market along its average cost curve. Therefore, no firm can undercut the incumbent. If the buyer prices off the average cost curve, then either entrants contest the positive profits or the buyer realizes negative profits. Because consumers are willing to pay prices greater than average costs for $q < q^*$, potential entry forces the incumbent to lower prices and increase quantity

[19] Here, as there, it also facilitates analysis of multiple countries and products, which we explore in Section 5.1.

such that the market clears where supply equals demand. The buyer is not willing to procure a greater quantity because she would incur losses.

Standard linear or CES demand systems may intersect downward sloping average costs multiple times. In that case, the intersection that determines the greatest equilibrium quantity must cut average costs from above. Otherwise, there is no equilibrium. If demand were to cut from below, then the buyer would procure an infinite quantity because average costs lie below demand forever. Therefore, under appropriate assumptions on the demand system, the market equilibrium is a corollary of Lemma 1.

Corollary 1. *If markets are contestable and demand intersects average costs from above at* q^* *and remains below average costs as* $q^* < q \to \infty$, *then a single buyer procures product from the seller and distributes it on the consumer market using the buyer's cost minimizing procurement system at optimal shipping frequencies.*

With these results at hand, we obtain the following proposition for the equilibrium response of shipping patterns and unit values to a change in the arrival rate of trade wars, taking into account the effect of this change on quantities as discussed in Proposition 4:

Proposition 5. *In equilibrium, a decrease in the probability that trade policy breaks up the relationship (a lower* ρ*), (i) increases shipment size but lowers price within the Japanese style procurement system; (ii) does not affect shipping patterns under the American procurement system; (iii) lowers shipment size if firms switch from the American to the Japanese procurement system; and (iv) raises shipment price if firms switch from the American to the Japanese procurement system* <u>*and*</u> *if the change of system effect dominates the equilibrium effect due to the increase in* q.

With endogenous procurement quantity q, the impact of ρ on unit values is not as sharp as when q is fixed because, as noted in Proposition 4, changes in q lower unit values. For sufficiently elastic demand, this channel may overturn the increase in unit values associated with a switch from the American to the Japanese procurement system. Nevertheless, the three cases outlined in Proposition 5 still allow us to empirically distinguish the procurement systems, as we demonstrate in the next section. They also provide us with an additional implication regarding the size of the change in the unit value for goods with different demand elasticities.

3 American versus Japanese Relationships in the Data

We examine the implications of the model using transaction-level U.S. import data from the U.S. Census Bureau's Longitudinal Foreign Trade Transaction Database (LFTTD). These data track every U.S. import transaction from 1992 to 2011 and include the dates the shipment left the exporting country and arrived in the United States, identifiers for the U.S. and foreign firm conducting the trade, the transaction value and quantity, a ten-digit Harmonized System (HS10) code classifying the product traded, and the country of origin of the exporter. We also observe whether the transaction is between related or arm's-length parties.[20]

In this section, we first describe the data along dimensions highlighted by the model, and discuss how the model assumptions map to the data. We then develop a procedure inspired by the model to classify U.S. importers as users of either the Japanese or American procurement systems, and examine whether their purhcase patterns are consistent with the model. Next, we investigate whether transactions between U.S. buyers and Chinese sellers became more consistent with Japanese procurement after a change in trade policy that increased the likelihood of trade peace between the United States and China.

3.1 Description of the Data

We refine the raw LFTTD data as follows. First, we drop all transactions that are warehouse entries, so that our dataset represents imports for consumption. Second, we remove all transactions that do not include an importer identifier, an exporter identifier, an HS code, a value, a quantity or a valid transaction date. Third, we use the procedure suggested by Pierce and Schott (2012) to create time-consistent HS codes, and correct an inconsistency in U.S. importing firms' identification codes over time by mapping firms in the LFTTD into the Longitudinal Business Database (LBD) and using the identifiers in the latter.[21] Fourth, we deflate transaction values using the quarterly

[20]Import transactions are defined to be between related parties if either party owns, controls or holds voting power equivalent to 6 percent of the outstanding voting stock or shares of the other organization. We classify observations with a missing related party identifier as related. For further information on the LFTTD, see Bernard, Jensen, and Schott (2009) and Kamal, Krizan, and Monarch (2015).

[21]The inconsistency arises due to a change in single-unit firms' identification codes in 2002. We drop observations for invalid exporter identifiers, e.g., those that do not begin with a letter (it should

Table 1: Relationship summary statistics

	Relationship Type	
	Arm's-Length	Related-Party
Total Value Traded	$228,874$	$1,757,764$
	(11,720,829)	(79,918,870)
Overall Length (Months)	32	66
	(77)	(130)
Total Number of Shipments	4	10
	(11)	(34)
Value/Shipment (VPS)	43,257	65,379
	(601,379)	(1,091,935)
Length/Shipment (LPS)	6	10
	(15)	(22)
Number of Relationships	24,138,500	7,523,500

Notes: Table reports the mean and standard deviation of each attribute across importer by exporter by country by ten-digit Harmonized System category quadruplets observed across the 1992 to 2011 sample period. First column summarizes arm's-length relationships while second column summarizes related-party relationships. Observations are restricted to quadruplets with more than one transaction. Value, length, and shipments refer to the total real value of imports , the duration in weeks, and the total number of shipments observed for the quadruplet. Number of observations has been rounded to the nearest 100 as per U.S. Census Bureau Disclosure Guidelines.

GDP deflator from the FRED database maintained by the Federal Reserve Bank of Saint Louis. Finally, we collapse the refined version of the data by U.S. importer (m), foreign exporter (x), origin country (c), week the export left the foreign country (w) and ten-digit HS product (h).

For each $mxch$ quadruplet with more than a single observation, we compute the total shipment value ($Value_{mxch}$), the number of weeks between the first and last observed shipment ($TotalLength_{mxch}$) and the total number of weeks during which a shipment is observed ($NumberShipments_{mxch}$), i.e., the number of observations for that quadruplet.[22] We note that $TotalLength_{mxch}$ can be subject to both left and right censoring.

The averages and standard deviations of these attributes are reported in Table 1, where the left panel contains results for arm's-length (AL) relationships and, for

start with the country name) or that have fewer than the requisite number of characters.

[22]Though the exporter identifier in the data includes information about the country of origin, we retain the use of the c subscript for clarity.

comparison, the right panel shows results for related-party (RP) relationships, which we drop from subsequent analysis.[23] As indicated in the table, the average AL quadruplet lasts for more than two years, with shipments on average every six weeks. The large standard deviations illustrate that there is considerable variation in the length and depth of quadruplets.

We reconcile the model and the data as follows. Buyers procure differentiated varieties. We interpret multiple buyers purchasing a particular HS product from a particular country as purchasing different varieties of that product. Sellers within a country and HS product code are capable of producing more than one variety within that product code without any costs to the buyer or seller beyond those described in Section 2.1. Thus, a seller transacting with multiple buyers supplies a different variety to each. Buyers trying to sell above average cost are susceptible, under our contestable market assumption, to another buyer purchasing the same variety from either the same or a different seller and selling it to downstream consumers at a lower price to capture the market. Consistent with the buyer's indifference to the identity of the seller under the American system, we assume that buyers using the American system can procure their variety from different sellers over time. Indeed, as discussed further below, we use the presence of multiple sellers within a buyer to identify use of the American system. Finally, we rationalize the fact that different buyers purchasing the same product from the same supplier might use different procurement systems by assuming that inspection costs can vary by variety within a product.

3.2 Identifying Japanese versus American Relationships, and their Attributes

A key implication of the model is that buyers purchasing under the American system transact with a larger number of foreign sellers than buyers under the Japanese system. In this section we use this implication to classify buyers as American or Japanese, and then investigate whether the transactions within these relationships are consistent with other predictions from the model. For this exercise, we use only the arm's-length U.S. import data described in the previous section.

[23]Results for AL relationships are restricted to relationships that never report an RP shipment. Results for RP relationships encompass all other relationships. We do not summarize the prices of AL vs RP relationships due to the potential influence of transfer pricing (see Bernard, Jensen, and Schott (2006)).

We classify transactions as being American or Japanese in three steps. First, we group transactions within importer by HS10 by country by mode of transportation bins. We include mode of transportation, indexed by z, to mitigate the influence of spurious sources of variation–e.g., variation in product quality within product-countries across modes–that could differ across different varieties of a product.[24] Then, for each $mhcz$ bin that appears within the 1992 to 2011 sample period, we compute the total number of distinct foreign exporters as well as the total number of transactions. The ratio of these sums is the average number of suppliers per shipment (SPS_{mhcz}). SPS_{mhcz} is higher when a U.S. importer uses a larger number of suppliers to obtain its import product, and has a maximum value of 1, indicating that the U.S. buyer used a different foreign exporter for every transaction within the bin. Because bins with few transactions might represent importers trying out a new product or other idiosyncrasies, we consider two classifications of bins according to whether they contain a minimum of either 5 or 15 transactions.[25] Finally, we classify a $mhcz$ bin as American or Japanese if its SPS_{mhcz} is above the 90th or below the 10th percentiles of the SPS across all c within the hz pair, respectively.[26] Bins whose SPS_{mhcz} are above the 10th percentile but below the 90th percentile receive no classification; they are excluded from our first descriptive analysis but are included later, as described below.

According to the model developed above, American transactions should be larger, less frequent and lower in price, and American relationships should be relatively short-lived. Accordingly, for each $mchz$ bin we compute: average quantity per shipment (QPS_{mhcz}), average number of weeks between shipments (WBS_{mhcz}), average price (i.e., unit value = value/quantity) per shipment (PPS_{mhcz}), and average mx pair length within the $mhcz$ bin ($Length_{mhcz}$). The latter variable is defined as the average length in weeks spanned by the first and last transactions associated with each exporter within the bin.

As an initial descriptive analysis, we consider only bins classified as American or Japanese–excluding the unclassified bins–and regress the four shipment attributes on a dummy variable for American bins and additional controls, as follows:

[24] The four main modes of transportation are vessel, rail, road, and air. We drop the small fraction of transactions that are transported by other means, e.g., hand-carried by passengers.

[25] Results are similar for other cutoffs, e.g., 10 or 20.

[26] We compute cutoffs across rather than within countries to account for the possibility that U.S. importers may choose to form Japanese relationships with suppliers from some countries but not with others. This method of computing cutoffs also allows us to obtain cross-country variation in the share of relationships classified as Japanese or American. A liability of this approach is that it assumes similarity of products within modes of transport across countries.

$$Y_{mhcz} = \beta_0 + \beta_1 American_{mhcz} + \beta_2 \ln(Quantity_{mhcz}) \qquad (7)$$
$$+ \beta_3 Begin_{mhcz} + \beta_4 End_{mhcz} + \lambda_{hc} + \lambda_z + \epsilon_{mhcz}.$$

Y_{mhcz} is one of the four attributes just described. $American_{mhcz}$ is an indicator variable that takes the value one for bins classified as American and a value zero for bins classified as Japanese using the procedure outlined above. To account for the likelihood that bins encompassing a larger level of imports might have larger transactions or different prices due, for example, to scale effects, the third term on the right-hand side controls for the total quantity transacted within the $mhcz$ bin, $Quantity_{mhcz}$, across all years. The next two terms, the week of the bin's first ($Begin_{mhcz}$) and last trade (End_{mhcz}) trade, capture potential time and duration effects.[27] Finally, λ_{hc} and λ_z are product-country and mode-of-transportation fixed effects. Together, these covariates allows us to compare American versus Japanese importers obtaining the same total quantity of the same product from the same country by the same mode of transportation. Standard errors are clustered at the hc level.

Results are reported in the top panel of Table 2. These regressions are restricted to bins with at least 5 transactions, but as reported in Table A.2 of Appendix B.1, results are similar for regressions restricted to bins with at least 15 transactions. In the first and second columns, we find that both the quantity per shipment (QPS_{mhcz}) and the number of weeks passed between shipments (WBS_{mhcz}) are more than one log point higher for bins classified as American. In the third and fourth columns, we find that bins classified as American exhibit transaction prices and relationship lengths that are -0.48 and -3.2 log points lower. In each case, estimates are statistically significant at conventional levels. In all four cases, relationships are consistent with the shipping attributes of the two systems outlined in Proposition 3 and with the long-term nature of Japanese-style relationships.

The bottom panel of Table 2 takes a broader approach to assessing the implications of the model by regressing the four outcome variables on SPS_{mhcz} rather than the $American_{mhcz}$ dummy variable used in the upper panel. As a result, the sample for

[27]We exclude the variable beg_{mhcz} from the regression using relationship length as dependent variable, since beg_{mhcz} and end_{mhcz} jointly are highly correlated with the average relationship length. Furthermore, for importers with only one supplier for a product-country-mode, their difference is exactly the same as relationship length.

Table 2: Classification regressions at the importer level, for $t = 5$

	(1)	(2)	(3)	(4)
Dependent Variable	ln(QPS)	ln(WBS)	ln(Price)	ln(Length)
d^{A5}_{mhcz}	1.221***	1.301***	−0.480***	−3.217***
	(0.003)	(0.003)	(0.005)	(0.004)
$\ln(Qty_{mhcz})$	0.756***	−0.242***	−0.355***	−0.025***
	(0.001)	(0.001)	(0.001)	(0.001)
Observations	388,000	388,000	388,000	388,000
R-Squared	0.957	0.739	0.844	0.805
Fixed Effects	hc, z	hc, z	hc, z	hc, z
	(5)	(6)	(7)	(8)
Dependent Variable	ln(QPS)	ln(WBS)	ln(Price)	ln(Length)
$\ln(SPS_{mhcz})$	0.473***	0.499***	−0.185***	−1.089***
	(0.001)	(0.000)	(0.001)	(0.001)
$\ln(Qty_{mhcz})$	0.783***	−0.219***	−0.385***	−0.063***
	(0.000)	(0.000)	(0.000)	(0.000)
Observations	2,239,000	2,239,000	2,239,000	2,239,000
R-Squared	0.952	0.579	0.816	0.579
Fixed Effects	hc, z	hc, z	hc, z	hc, z

Notes: Superscripts *, **, and *** indicate statistical significance at the 10, 5, and 1 percent levels, respectively. Number of observations has been rounded to the nearest 1000 as per U.S. Census Bureau Disclosure Guidelines.

these regressions include all $mhcz$ bins containing at least five transactions rather than just the subset of bins classified explicitly as American or Japanese. Results are qualitatively similar. In terms of magnitude, we find that a one percent increase in suppliers per shipment is associated with increases in the value traded per shipment and weeks between shipments of 0.47 and 0.50 percent, and declines in the average transaction price and average relationship length of -0.19 and -1.09 percent.

Together, the results in the top and bottom panels of Table 2 indicate that classifying importers based on the number of foreign suppliers per transaction – one dimension by which American and Japanese-style procurement can be distinguished – yields results for average order size, frequency, order price, and relationship length that are consistent with the model. Buyers that are more apt to be American receive relatively large shipments relatively less frequently at a lower relative price from sellers with whom they have relatively short relationships.

Next, we provide a more stringent assessment of Proposition 3 by comparing the same seller's transaction patterns across buyers that we classify as sourcing under different systems. As discussed above, we interpret a given seller transacting the same product with multiple buyers as transactions in different varieties within that product. Differences in inspection costs across varieties within the same product code give rise to differences in procurement systems. Assuming that production costs across varieties within the same seller-product-mode of transportation are similar, this specification allows us to isolate more cleanly how procurement patterns change with the number of suppliers a buyer sources from by controlling for unobservable differences across suppliers, such as differences in production costs. Thus, we estimate equation (7) at the importer-exporter-country-product-mode ($mxhcz$) level to exploit variation *within sellers*,

$$
\begin{aligned}
Y_{mxhcz} = \beta_0 + \beta_1 American_{mhcz} + \beta_2 \ln(Quantity_{mxhcz}) \qquad\qquad (8)\\
+ \beta_3 Beg_{mxhcz} + \beta_4 End_{mxhcz} + \beta_5 \ln(AvgLength_{mxhcz}) + \lambda_{xhc} + \lambda_z + \epsilon_{mxhcz}.
\end{aligned}
$$

In this specification shipment attributes are redefined to include the exporter dimension: e.g., QPS_{mxhcz} is the average quantity shipped by exporter x to buyer m within the $mhcz$ bin. On the right-hand side, we redefine $Begin_{mxhcz}$ and End_{mxhcz} to be the beginning and ending week of the particular mx relationship within the bin. We include an additional control variable, $AvgLength_{mxhcz}$, which is defined as the average of the relationship length of the mx relationship within the bin at each transaction. This variable is lower for mx pairs that trade more when they are young and accounts for the fact, reported in Heise (2015), that trading patterns vary with relationship age. Note that for left-hand-side attribute $Length_{mxhcz}$, the variables $Begin_{mxhcz}$ and $AvgLength_{mxhcz}$ are excluded from the regression because that attribute is equal to the difference of $Begin_{mxhcz}$ and End_{mxhcz}, and overall relationship length is highly correlated with its average. Finally, we include exporter-product-country (xhc) fixed effects to compare buyer prices within sellers. Standard errors are clustered at the importer-HS10-country level.

Results using the $American_{mhcz}$ dummy variable and SPS_{mhcz} are presented in the top and bottom panels of Table 3. In both cases, estimates are consistent with those in Table 2. Namely, in the top panel we find that for a common seller, the average buyer classified as American purchases 0.42 log points more quantity per shipment and receive shipments spaced more than twice as far apart, relative to a buyer classified

Table 3: Classification regressions at the importer-exporter level, for $t = 5$

	(1)	(2)	(3)	(4)
Dependent Variable	ln(QPS)	ln(WBS)	ln(Price)	ln(Length)
d^A_{mhcz}	0.417***	1.296***	−0.088***	−0.299***
	(0.021)	(0.040)	(0.024)	(0.032)
$\ln(Qty_{mxhcz})$	0.549***	−0.233***	−0.105***	0.218***
	(0.001)	(0.002)	(0.001)	(0.002)
Observations	183,000	183,000	183,000	183,000
R-Squared	0.981	0.790	0.969	0.719
Fixed Effects	xhc, z	xhc, z	xhc, z	xhc, z

	(5)	(6)	(7)	(8)
Dependent Variable	ln(QPS)	ln(WBS)	ln(Price)	ln(Length)
SPS_{mhcz}	0.288***	0.551***	−0.077***	−0.173***
	(0.001)	(0.002)	(0.001)	(0.001)
$\ln(Qty_{mxhcz})$	0.659***	−0.176***	−0.151***	0.155***
	(0.000)	(0.001)	(0.001)	(0.001)
Observations	1,686,000	1,686,000	1,686,000	1,686,000
R-Squared	0.980	0.688	0.957	0.617
Fixed Effects	xhc, z	xhc, z	xhc, z	xhc, z

Notes: Superscripts *, **, and *** indicate statistical significance at the 10, 5, and 1 percent levels, respectively. Number of observations has been rounded to the nearest 1000 as per U.S. Census Bureau Disclosure Guidelines.

as Japanese. Moreover, within sellers, buyers classified as American pay prices that are on average -0.08 log points lower, and have relationships that are -0.30 log points shorter.[28].

3.3 Commodities versus Differentiated Goods

To the extent that differentiated goods are more costly to inspect than commodities, buyers may be more likely to purchase them using the Japanese procurement system. In this section, we investigate this possibility using the product categorization scheme proposed by Rauch (1999), which classifies products according to whether they are traded on an organized exchange, have a reference price, or neither of these attributes, where the latter are considered differentiated. Rauch (1999) provides both a liberal and a conservative version of these definitions. We use the liberal definition for the

[28] Here, too, we find similar results using a cutoff of 15 transactions in Table A.3 of Appendix B.1).

results reported in the main text, but show that these results are robust to using the conservative definition in Table A.4 in the Appendix.

For this analysis, we use a specification of the form

$$Y_{mhcz} = \beta_0 + \beta_1 d_h^{Differentiated} + \beta_2 d_h^{Reference} + \beta_3 \ln(Value_{mhcz}) + \beta_4 Beg_{mhcz} + \beta_5 End_{mhcz} + \lambda_{mc} + \lambda_z + \epsilon_{mhcz}, \tag{9}$$

where $d_h^{Differentiated}$ and $d_h^{Reference}$ are dummy variables indicating two of the three Rauch categories – that the product is differentiated or has a reference price. Being traded on an exchange, i.e., the category most likely to capture commodities, is the left-out category. Beg_{mhcz} and End_{mhcz} are defined as before. $Value_{mhcz}$ represents the total (deflated) value traded within the $mhcz$ bin, while λ_{mc} and λ_z are importer-country and mode of transportation fixed effects. As before, we include only bins with at least 5 transactions, and standard errors are clustered at the product-level. Note that we do not include the average price or quantity per shipment in these regressions, since prices and quantities vary across products for many reasons.

The first three columns of Table 4 present the regression coefficients for the two Rauch dummies; the remaining estimates are not reported but available upon request. We find that differentiated products exhibit smaller values per shipment (column 1) as well as more frequent shipments (column 2) than commodities, and that the average length of relationships is longer (columns 3). Comparison of the estimates for $d_h^{Differentiated}$ and $d_h^{Reference}$ reveal that goods with reference prices appear more Japanese than commodities, but less Japanese than differentiated products, at least with respect to value per shipment and weeks between shipment.

One potential concern with the previous specification is that importers purchasing differentiated products may have mechanically more suppliers per product code due to their purchasing of multiple varieties within differentiated products. A single buyer selling more varieities could lead to spuriously smaller observed shipments from each supplier and to shorter relationships with each. To account for this possibility, the last three columns of 4 include the total number of suppliers for the importer-product-country-mode bin ($NumberSupliers_{mhcz}$) as an additional regressor. Intuitively, we find that after add this control, differentiated products have a slightly longer average relationship length than products with reference prices, and exhibit smaller, more fre-

Table 4: Rauch Regressions for $t = 5$ (Liberal Classification)

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent Variable	ln(VPS)	ln(WBS)	ln(Length)	ln(VPS)	ln(WBS)	ln(Length)
d_h^D	-0.198^{***}	-0.195^{***}	0.135^{***}	-0.161^{***}	-0.164^{***}	0.185^{***}
	(0.003)	(0.004)	(0.006)	(0.003)	(0.004)	(0.005)
d_h^{Ref}	-0.120^{***}	-0.118^{***}	0.205^{***}	-0.137^{***}	-0.132^{***}	0.183^{***}
	(0.003)	(0.004)	(0.006)	(0.003)	(0.004)	(0.006)
$\ln(NSupp_{mhcz})$				-0.456^{***}	-0.374^{***}	-0.608^{***}
				(0.001)	(0.001)	(0.002)
Observations	$1,556,000$	$1,556,000$	$1,556,000$	$1,556,000$	$1,556,000$	$1,556,000$
R-Squared	0.874	0.700	0.532	0.904	0.727	0.585
Fixed Effects	mc, z	mc, z	mc, z	mc, z	mc, z	mc, z

Notes: Superscripts *, **, and *** indicate statistical significance at the 10, 5, and 1 percent levels, respectively. Number of observations has been rounded to the nearest 1000 as per U.S. Census Bureau Disclosure Guidelines.

quent shipments.[29] Overall, we review the results in this section as providing encouraging support for the model presented in Section 2. To our knowledge, it also represents the first empirical investigation into the procurement systems posed by Taylor and Wiggins (1997).

4 The Effect of PNTR on the Choice of Procurement System

The model presented in Section 2 suggests that the share of American and Japanese procurement relationships in the economy can vary with trade policy. In particular, a decrease in the possibility of a trade war can induce buyer and seller to switch from the American to the Japanese system. Such a switch may lower procurement costs and increase consumer welfare. We study this implication using a plausibly exogenous change in U.S. trade policy, the U.S. granting of PNTR to China in October 2000.

[29] Table A.4 in Appendix B.1 shows our results under the conservative Rauch classification. Our findings are further strengthened under that specification.

4.1 Description of PNTR

U.S. imports from non-market economies such as China are generally subject to relatively high non-NTR tariff rates originally set under the Smoot-Hawley Tariff Act of 1930, compared to the generally low NTR tariff rates the U.S. offers to trading partners that are members of the World Trade Organization (WTO). A provision of U.S. trade law, however, allows imports from non-market economies to enter the United States under NTR tariffs subject to *annual* approval by both the President and Congress. Chinese imports first began entering the United States under this provision in 1980, after the warming of relations between the United States and China. Annual approval became controversial and less certain after the Tiananmen incident in 1989, however, and this uncertainty continued throughout the 1990s. U.S. extension of PNTR in 2000 eliminated the need for these annual renewals, thereby eliminating the possibility of sharp increases in tariffs on a wide range of Chinese exports. Note that this policy change did not affect actual tariffs, and would therefore have no effect on trade flows in models such as in Eaton and Kortum (2002), while in our framework it affects ρ and hence the procurement costs under the Japanese system.

We assess an import product's exposure to PNTR in terms of its NTR gap, i.e., the difference between the relatively low NTR tariff rate that was locked in by the change in policy and the higher rate to which it might have risen,

$$NTR\,Gap_h = Non\ NTR\ Rate_h - NTR\ Rate_h. \tag{10}$$

We compute these gaps for 1999, the year before the change in policy, using *ad valorem* equivalent tariff rates provided by Feenstra, Romalis, and Schott (2002).[30] As indicated in Figure 2, these gaps vary widely across products, and have a mean and standard deviation of 0.32 and 0.23. Our identification strategy exploits this variation in the NTR gap to determine whether U.S.-China procurement patterns change relative to procurement patterns with exporters from other source countries (first difference) after the change in U.S. policy is implemented (second difference) in industries with higher NTR gaps (third difference). The last difference captures the fact that industries with larger NTR gaps experience a larger increase in the relationship continuation probability than industries with smaller gaps. We expect the largest shifts toward

[30] While U.S. tariffs are set at the level of eight-digit HS products, we observe trade at the ten-digit HS level. We therefore match each ten-digit HS product with the tariff associated with its first eight digits.

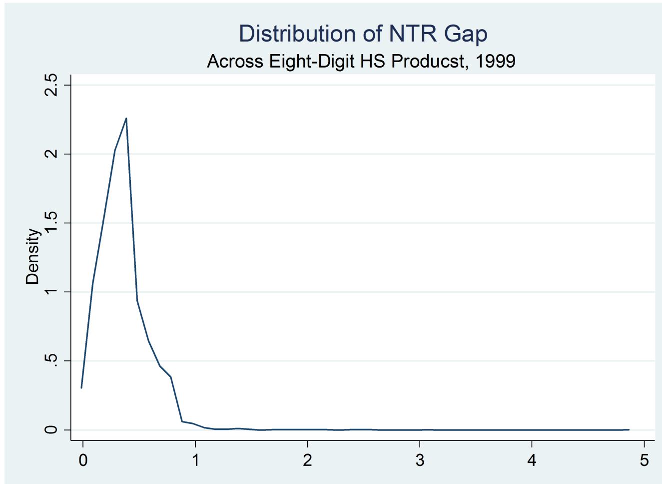


Figure 2: Distribution of the NTR Gap Across Import Products

Japanese-style procurement after PNTR to occur in U.S. imports of high-gap products from China.

4.2 American versus Japanese Relationships Before versus After PNTR

Before proceeding to formal regression analysis, we plot the share of Japanese relationships in U.S.-China trade over time using an approach similar to the one described in the previous section. First, we divide the sample period into four time windows: 1992 to 1996, 1997 to 2001, 2002 to 2006, and 2007 to 2011. Then, for each of these four windows, we compute the number of suppliers per shipment for each $mhcz$ bin with at least five transactions in each period p, SPS^{p}_{mhcz}. We classify importer-exporter-product bins as Japanese based on the 10th percentile of the SPS_{mhcz} distribution for the 1997 to 2001 time period, i.e., the period just before the change in trade policy. This same cutoff for classifying bins as Japanese is used for all time periods. Note that while 10 percent of bins are classified as Japanese during the second time period by construction, the share of bins classified as Japanese in the other windows can vary. Finally, we compute the value-weighted average share of bins that are Japanese across HS10 codes and modes of transportation for each window, both for U.S. imports from China and for U.S. imports with the rest of the world. Table 5 provides some details on the share of Japanese-style relationships for U.S. trade with its 10 largest trading

Table 5: Share of Japanese-Style Relationships by Country, 1992-2001

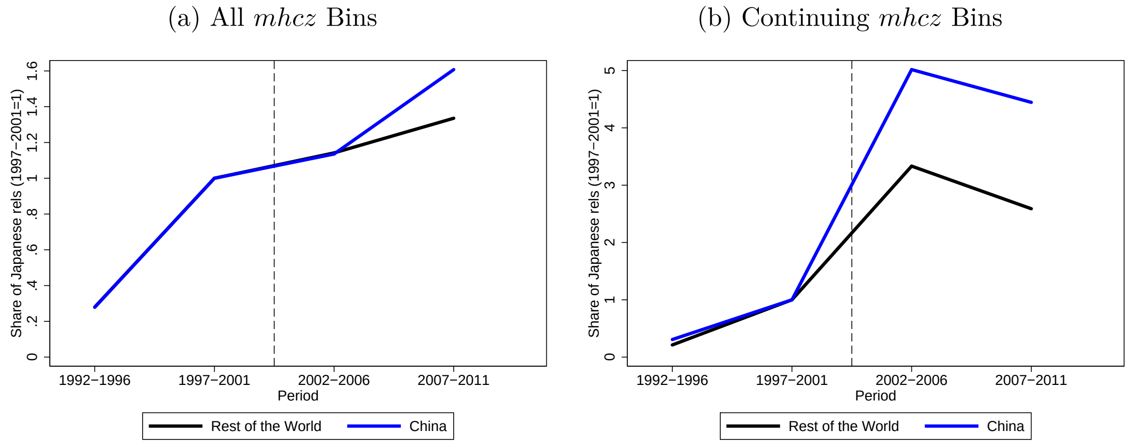
Country	Share of Japanese	Country	Share of Japanese
Mexico	14.27%	United Kingdom	8.33%
Japan	11.27%	South Korea	8.18%
Germany	9.63%	Brazil	7.50%
Rest of the World	9.50%	France	6.29%
Canada	9.16%	China	5.32%
Taiwan	8.92%		

partners and with the rest of the world just prior to the policy change. For this table, we compute a value-weighted average over the share of relationships classified as Japanese in the first two time windows (1992 to 1996 and 1997 to 2001), for each country. We find that Japanese-style relationships account for approximately 5.3 percent of all U.S.-China imports in the pre-PNTR period. This share is significantly smaller than for any other country among the largest trading partners. We expect trade with Japan to exhibit a high share of Japanese-style relationships, since firms such as Toyota are well known to have close relationships with suppliers and customers, and that is what we find in the data. Mexico has the highest share of Japanese-style relationships, possibly due to the close supply chain integration with the U.S, including maquiladora trade.

Figure 3a shows the evolution of the share of Japanese-style relationships in total trade relative to the 1997 to 2001 period, which we normalize to one. As indicated in the figure, the share of Japanese relationships increases over time. In the 2002 to 2006 period, which immediately follows PNTR, the share of Japanese relationships grows by about 20 percent compared to the 1997 to 2001 period, both for U.S.-China trade and for trade with the rest of the world. However, in the 2007 to 2011 period, trade with China exhibits a much larger increase in the share of Japanese relationships (61 percent above the baseline level in 1997 to 2001) versus trade with other countries (34 percent above the baseline). The relative increase in the share of Japanese relationships in trade with China following PNTR in the later period is broadly consistent with our framework, and the lack of an immediate effect after PNTR might be due to a large number of U.S. importers exploring importing from China and forming new relationships after 2001.[31] To remove the effect of a possible surge in relationship for-

[31] In fact, we show below that after PNTR a large number of new relationships were formed with Chinese suppliers and these were often short-lived.

Figure 3: Share of Japanese-Style Relationships in U.S. Trade



mation following 2001, we compute the same figure for only importer-exporter-product triplets that exist both before PNTR (trading at least once before 2001) and after PNTR (trading at least once from 2002 onwards). Focusing on this sub-sample allows us to examine how PNTR affects continuing relationships. Figure 3b highlights that there is a substantial increase in the share of Japanese-style relationships with China in the period immediately following PNTR, and this increase is much stronger than the increase for the rest of the world. The share of Japanese-style relationships with China increased by a factor of 5 in the 2002 to 2006 period compared to the period 1997 to 2001, indicating a substantial switch towards Japanese-style procurement. While the preceding analaysis is suggestive of a relationship between PNTR and firms' choice of procument systems, it has ignored the substantial variation in potential tariff rate increases across products that had been possible prior to the policy change. We consider a more formal examination of PNTR in the following sub-section.

4.3 Estimating the Effect of PNTR on Procurement

Proposition 5 characterizes how relationship attributes change in response to a reduction in trade peace. If the reduction is insufficient to induce a change in system, the attributes of American relationships do not change, while Japanese relationships experience reductions in price and shipment frequency, and increases in shipment size. For relationships that switch from American to Japanese, shipment size falls and shipment frequency rises, while prices can fall or rise depending on whether the endogenous change in overall order quantity (q) is dominant or is dominated by the switching effect.

Our first, preferred specification for examining the impact of a decline in the probability of a trade war on choice of procurement system compares shipments within importer-exporter-product-country quadruplets across two symmetric time intervals around the change in U.S. trade policy, $p \in \{Pre, Post\}$,

$$\begin{aligned} ln(\overline{Y}_{mxhcp}) =& \beta_0 + \beta_1 1\{p = Post\} * 1\{c = China\} * NTR\,Gap_p + \gamma\chi_{mxchp} \\ &+ \beta_2 ln(Total\,Value_{mxhcp}) + \lambda_{mxh} + \lambda_c + \lambda_p + \epsilon_{mxhcp} \end{aligned} \tag{11}$$

where subscripts m, x, h and p index U.S. importers, exporters from country c, ten-digit HS products and time period. The regression sample consists of all shipments by "always-arm's-length" parties, i.e., parties that engage solely in arm's length transactions over the entire 1992 to 2011 sample period, so long as there is at least one shipment in each period. Periods are one of two distinct five-year windows around 2001, either 1995 to 2000 (pre period) or 2002 to 2007 (post period). Note that the latter window ends before the Great Recession, and also before we observe the largest increase in the share of Japanese-style relationships with China in the simple plot in Figure 3a.

$\overline{Y}_{mxhcp}$ represents one of several attributes of the shipment patterns within an $mxhcp$ bin deemed relevant by the model developed in Section 2 and discussed above: WBS_{mxhcp} is the average number of weeks between shipments, VPS_{mxhcp} is the average value per shipment, QPS_{mxhcp} is the average quantity per shipment, $Price_{mxhcp}$ is the average unit value per shipment, and $Length_{mxhcp}$ is the average length in weeks of the importer-exporter-product relationships appearing within the $mxhcp$ bin.[32] The matrix χ_{mxhcp} represents the full set of interactions of the NTR gap, the post dummy variable ($1\{p = Post\}$) and the China dummy variable ($1\{c = China\}$) required to identify β_1. $TotalValue_{mxhcp}$ is the total value of all shipments occurring within the $mxhcp$ bin; its inclusion accounts for the varying scale of imports across bins. Relationship (mxh), country and period fixed effects are represented by λ_{mhx}, λ_c and λ_p. The difference-in-differences coefficient of interest, β_1, measures the log difference in activity for shipments from China versus other countries after the change in U.S. policy versus before for products with higher versus lower NTR gaps. From the model

[32]As above, the length of each relationship is defined as the number of weeks between the first observed transaction during the period and the last observed transaction during the period.

presented in Section 2, we expect $\beta_1 < 0$ for VPS_{mxhcp}, QPS_{mxhcp} and WBS_{mxhcp}, and $\beta_1 > 0$ for $Price_{mxhcp}$ and $Length_{mxhcp}$ if PNTR induced a switch from the American to the Japanese system.

Our second specification ignores exporter identity and analyzes shipments within importer-products across periods,

$$\begin{aligned} ln(\overline{Y}_{mhcp}) =&\beta_0 + \beta_1 1\{p = Post\} * 1\{c = China\} * NTR\,Gap_p + \gamma\chi_{mhcp} \\ &+ \beta_2 ln(Total\,Value_{mhcp}) + \delta_{mh} + \delta_c + \delta_p + \epsilon_{mhcp} \end{aligned} \tag{12}$$

Here, too, the regression sample includes all shipments by "always-arm's-length" parties so long as there is at least one shipment for each *mhcp* bin. After the procurement attributes are computed, the *mxhcp* data are collapsed to the *mhcp* level so that there is one observation – the average – in the regression for each *mhcp* bin.

Our final specification ignores both importer and exporter identity and analyzes shipments within products across periods,

$$\begin{aligned} ln(\overline{Y}_{hcp}) =&\beta_0 + \beta_1 1\{p = Post\} * 1\{c = China\} * NTR\,Gap_h + \gamma\chi_{hcp} \\ &+ \beta_2 ln(Total\,Value_{hcp}) + \delta_h + \delta_c + \delta_p + \epsilon_{hcp} \end{aligned} \tag{13}$$

As above, we require at least one shipment within each *hcp* bin, and the data are collapsed to the *hcp* level after the procurement attributes are computed.

Results for the first, second and third specifications are reported in the corresponding three columns of Table 6, where each row reports the estimated DID term coefficient and standard error for a different relationship attribute. Starting with the preferred, within-*mxh* results reported in column 1, we find that all estimates of β_1 are consistent with a switch towards Japanese procurement: point estimates for value per shipment, quantity per shipment and weeks between shipments are all negative, though statistically significant only for the first two, while they are positive and statistically significant for shipment price and overall length. In terms of economic significance, these results imply that a one standard deviation increase in the NTR gap (0.23) is associated with relative declines in shipment value and shipment quantity of 1.6 and 3.0 percent after the change in U.S. policy. Shipment price and relationship length, by contrast, rise by 0.9 and 2.3 percent, respectively.

Table 6: PNTR and procurement

Dependent Variable	Within Importer-Exporter-Product	Within Importer-Product	Within Product
ln(Value per Shipment)	-0.07^{***}	-0.05^{***}	-0.17^{***}
	0.01	0.01	0.05
ln(Quantity per Shipment)	-0.13^{***}	-0.04^{**}	-0.04
	0.02	0.02	0.10
ln(Price per Shipment)	0.04^{**}	-0.04^{**}	-0.11
	0.02	0.02	0.09
ln(Weeks between Shipments)	-0.04	-0.06^{***}	-0.36^{***}
	0.03	0.02	0.07
ln(Overall Relationship Length)	0.10^{***}	0.00	-0.34^{***}
	0.04	0.03	0.08
Observations	$752,600$	$1,011,700$	$324,300$
Sample	$mxhcp$	$mhcp$	mcp
Fixed Effects	mxh, c, p	mh, c, p	h, c, p

Notes: Table summarizes the results of generalized differences-in-differences regressions of relationship attributes on a DID coefficient representing the interaction of the NTR gap and dummy variables representing the post-PNTR period and trade with China (see text). Each cell in the table represents the result of a different regression. Data are collapsed to the importer-exporter-product-country-period (*mxhcp*) level in column 1, the importer-product-country-period (*mhcp*) level in column 2, and the product-country-period (*hcp*) level in column 3. Sample is restricted to bins with at least two observations for the pre- and post period. Dependent variables are computed with respect to the noted sample bins. Results for fixed effects and other covariates needed to identify the DID coefficient of interest are suppressed. Superscripts *, **, and *** indicate statistical significance at the 10, 5, and 1 percent levels, respectively. Number of observations has been rounded to the nearest 100 as per U.S. Census Bureau Disclosure Guidelines.

Comparison of the within-relationship results in column 1 with the within-product results in column 3 provides further intuition for our theoretical framework, and illuminates our findings in the initial analysis of the share of Japanese-style relationships. For example, the relatively large (in absolute terms) DID point estimates for VPS_{hcp}, WBS_{hcp} and $Length_{hcp}$ reflects the fact that the change in U.S. policy gave rise to many new relationships. Since many of these relationships involved firms that had not imported from China before (see Pierce and Schott (2016)), it is unsurprising that they were short-lived and perhaps encompass smaller, trial-size shipments.

5 Quantitative Analysis

5.1 Multi-Country Model

Environment

We now embed our model into the multi-country framework of Eaton and Kortum (2002). This framework will allow us to expand our assessment of how changes in the probability of a trade war affect firms' procurement choices, by also determing effects on trade flows and consumption. Our model generalizes the Eaton and Kortum (2002) setup to the case with downward sloping marginal costs by modifying their assumption of perfect competition to a contestable markets setup. We will estimate the model below.

The economy consists of three countries indexed by n. In the estimation below, we will interpret these countries to be the U.S., China, and the Rest of the World, respectively.[33] Each country is populated by L_n consumers, who purchase a continuous flow of goods from a manufacturing sector and a non-manufacturing sector to maximize a Cobb-Douglas utility of the form $Z_n^{1-\alpha}Q_n^{\alpha}$, where Z_n is the quantity of the non-manufactured good and Q_n is the quantity of a composite manufactured good. The composite is a CES aggregate of a continuum of differentiated products indexed by $\omega \in [0, 1]$,

$$Q_n = \left(\int_0^1 q_n(\omega)^{(\sigma-1)/\sigma} d\omega\right)^{[\sigma/(\sigma-1)]} \tag{14}$$

where $\sigma > 0$ is the elasticity of substitution and $q_n(\omega)$ is the quantity bought of product ω. Consumers purchase the manufactured goods ω at prices $p_n(\omega)$ from a continuum of buyer firms in each country n. Country n's price index for manufactured goods is thus

$$p_n = \left(\int p_n(\omega)^{1-\sigma} d\omega\right)^{1/(1-\sigma)}. \tag{15}$$

Each manufactured product is produced byfirms operating with the linear production function $x = \frac{\Upsilon}{\theta}l$. Labor is paid the wage rate w_i in country i. The productivity Υ is specific to each origin country-product combination and drawn from a Frechet distribution according to

$$F_i(\Upsilon) = e^{-T_i \Upsilon^{-\zeta}}, \tag{16}$$

[33] Our model generalizes to an arbitrary number of countries. However, for our purposes three are sufficient.

where the country-specific parameter T_i scales the mean of the distribution, and ζ is the variance. The draws are independent across products within each country. We assume that a country's firms are owned by the household.

We depart from the assumption of perfect competition in Eaton and Kortum (2002) and assume that within each product-destination country pair in the manufacturing sector buyers compete in a contestable market. In each such market, trade between buyers and manufacturers takes place in the way described in Section 2. Buyers compete to procure a given quantity $q_n(\omega)$ by choosing the origin country i, shipping system $s \in \{A, J\}$, and shipment size $x^*_{ni,s}(\omega)$ such that long-run average costs (5) are minimized. Manufacturing firms incur fixed costs f in units of labor, and buyers choosing the American system need to use an additional $m_i(\omega)$ origin country labor units to inspect the quality of product ω before it is shipped. The manufacturing country-product specific inspection costs $m_i(\omega)$ are drawn from a distribution $G_i(m) \sim N(\bar{m}, \sigma^2_m)$.

Nonmanufacturing output can be costlessly traded across countries, and is therefore used as numeraire. We assume that each consumer supplies one unit of labor, and let aggregate expenditures in country n be given by W_n, of which α is spent on manufactures. To close the model, we follow one of the two cases considered in Eaton and Kortum (2002) and assume that labor is perfectly mobile between manufacturing and non-manufacturing. The non-manufacturing sector is sufficiently large so that at least some of its output is produced. The wage rate w_n is then exogenously pinned down by the productivity of the non-manufacturing sector, and the country's total wage income is $w_n L_n$ regardless of the allocation of workers to manufacturing and non-manufacturing.

Equilibrium

Equilibrium requires that buyer firms minimize costs such that the contestable market equilibrium is feasible and sustainable, the household maximizes the CES objective, and the goods and labor markets clear.

Buyer firms in country n compare the average costs $AC_{ni,s}(x^*_{ni,s}, q_n(\omega))$ of purchasing a quantity $q_n(\omega)$ across all systems s and origin countries i to minimize overall average costs

$$AC_n(q_n(\omega))^* = \min\left\{\min\left\{AC_{ni,A}(x^*_{ni,A}(\omega), q_n(\omega)), AC_{ni,J}(x^*_{ni,J}(\omega), q_n(\omega))\right\};\ i = 1, ..., N\right\}, \tag{17}$$

where $x^*_{ni,s}(\omega)$ is the optimal batch size for each country-system combination determined by the first-order condition (6).[34] Since marginal costs are downward sloping in q, in equilibrium there will only be one buyer in each market as shown in Section 2, and this buyer procures under one system from exactly one seller country, the one with the lowest average costs. Denote by $I_{ni,s}(\omega)$ an indicator function that is equal to one if the buyer in country n procures product ω from country i under system s, and zero otherwise. The contestable market price is $p_n(\omega) = AC_n(q_n(\omega))^*$. Seller firms obtain profits $\pi^s_{ni,s}(\omega)$ per order cycle that are equal to the incentive premium under the Japanese system and zero under the American system.

The household chooses consumption of manufactured goods to maximize (14) subject to the budget constraint

$$\int_0^1 p_n(\omega)q_n(\omega)\, d\omega \leq \alpha\left(w_n L_n + \sum_{n'}\sum_s \int \pi^s_{n'n,s}(\omega) I_{n'n,s}(\omega) d\omega\right), \tag{18}$$

where α is the fraction spent on manufactured goods. The new term here relative to the original Eaton and Kortum (2002) represents the profits arising from shipments to countries n' under $s = J$.

Goods market clearing implies

$$\sum_n \sum_i \sum_s I_{ni,s}(\omega) x^*_{ni,s}(\omega) = \sum_n \sum_i \sum_s I_{ni,s}(\omega) \int_0^{x^*_{ni,s}(\omega)/q_n(\omega)} q_n(\omega) dt \quad \forall\omega, \tag{19}$$

where the left-hand side of the equation indicates worldwide production of product ω and the right-hand side is its worldwide consumption. Labor market clearing requires that

[34]In the estimation below, we trace out the AC curves in each market as a function of $q_n(\omega)$. We then find the equilibrium, holding these AC curves fixed, by finding demand curves that are consistent with utility maximization and the aggregate price level.

$$L_i - L_i^N - f\sum_{n'}\sum_{s}\int_0^1 I_{n'n,s}(\omega)d\omega - \sum_{n'}\int_0^1 I_{n'n,A}(\omega)m_n(\omega)d\omega$$
$$= \sum_{n'}\sum_{s}\int_0^1 \frac{\bar{\theta}}{\Upsilon_n(\omega)} I_{n'n,s}(\omega)q_{n'}(\omega)d\omega \quad \forall i \in N, \tag{20}$$

where the left-hand side is total labor supply in country i minus the labor supplied to non-manufacturing, L_i^N, labor used for fixed costs, and labor used for inspection costs, respectively, and the right-hand side indicates the instantaneous labor demand.

Definition 1. A competitive equilibrium consists of prices $p_n(\omega)$, quantities $q_n(\omega)$, and shipping sizes $x_{ni,s}(\omega)$ such that (i) given $q_n(\omega)$, buyers choose the manufacturing country i, the procurement system s, and order size $x^*_{ni,s}(\omega)$ to minimize average costs (17) and set prices $p_n(\omega) = AC_n(q_n(\omega))^*$ to win the contestable market, (ii) given prices $p_n(\omega)$ the household chooses quantities $q_n(\omega)$ to maximize (14) subject to the budget constraint (18), (iii) the goods market clears and (iv) the labor market clears.

A trade war of country i with country n leads importers in i sourcing from n (and vice versa) to switch their procurement of these varieties to other countries. This switching occurs at different times for each variety, dependent on when the variety's inventory runs out. Given the contestable market assumption, importers' continuation value in the post-trade war period is exactly zero. Furthermore, since households order continuously, they immediately adjust their quantities ordered $q_n(\omega)$ to reflect new prices in a trade war, and therefore households' ordering choices always reflect the current state of the world. Households do not face any uncertainty about the quantities they will actually receive.

5.2 Model Properties

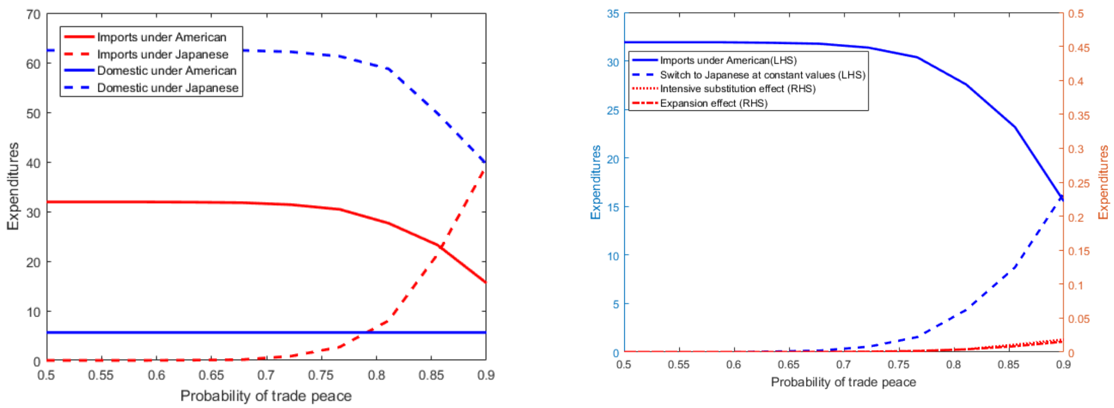
We now examine how the equilibrium changes as we vary the parameters of the model in a two-country setup. Unless otherwise mentioned, all parameters are at their baseline values as described in the next section. In the next section, we study how the specific episode of PNTR affected the U.S. economy.

We begin by examining the effect of the probability of trade peace $\Psi_{ni} \equiv e^{-\rho_{ni}}$ on country n's choice of procurement system and source country. The choice of country

Figure 4: Imports vs. Continuation Probability (Ψ)

(a) Expenditures by System and Country

(b) Decomposition of Imports under the American System



and system is shaped by three factors: countries' product-specific productivity, countries' product-specific inspection costs, which only matter in the American system, and the probability of trade peace, which matters only in the Japanese system. When Ψ_{ni} is low, no goods are imported under the Japanese system since the incentive premium is prohibitive. Products in which the foreign country's productivity is high or inspection costs are low are imported under the American system. These products must be cheaper than sourcing domestically under the Japanese system, where the probability of trade peace is one. Products whose domestic inspection costs are sufficiently low to be preferable to Japanese sourcing are purchased domestically under the American system. Productivity must be high and inspection costs low relative to the foreign country for these products to make domestic sourcing preferable. Finally, products with relatively high domestic inspection costs but an intermediate productivity level that makes foreign sourcing unattractive are sourced domestically under the Japanese system.

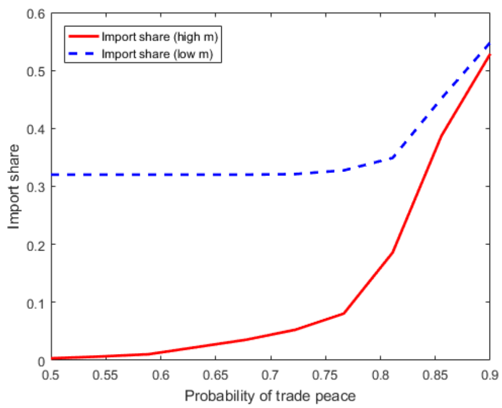
Figure 4a shows the value of goods purchased by country and system as Ψ_{ni} increases, for example due to trade policies such as accession to the WTO. As a result of this increase, imports under the Japanese system rise, for two main reasons. First, some products previously imported under the American system switch to importing under the Japanese system. For these products, the higher probability of trade peace lowers the incentive premium, making the Japanese system more desirable. . Second, some products switch from domestic Japanese sourcing to Japanese imports. For these products the domestic economy is relatively unproductive, and so for a sufficiently high trade peace probability, sourcing from abroad dominates domestic sourcing even though domestic trade wars never occur. Finally, domestic purchases under the American system never switch systems given a change in the trade peace probability. Intuitively, these products must be cheaper than imports under the Japanese system from any country since they are cheaper than Japanese domestic sourcing, and so only changes in inspection costs or productivity could lead these products to switch source country.

Figure 4b decomposes the decline in imports under the American system in the previous figure further. As the trade peace probability rises, products switch from American to Japanese imports. The effect of this switch, holding the value traded constant, is illustrated by the fall of the solid and the rise of the dashed line in Figure 4b. In addition, there is also a (small) intensive margin substitution effect (dotted line). This effect captures that products that continue to be imported under the American system have now become more expensive relative to products that are newly imported under the Japanese system, which due to the CES aggregator leads to a shift in the value imported towards the latter. Finally, there is a trade expansion effect because the import price index falls, which allows consumers to spend more (dashed and dotted line).

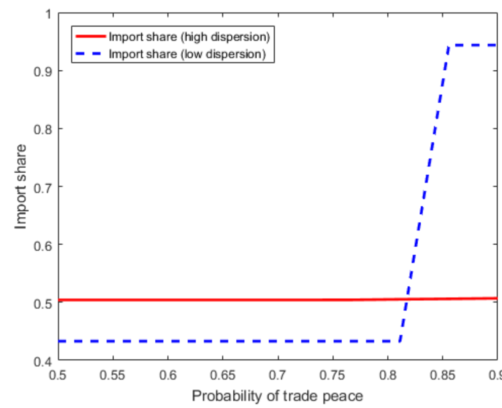
The effect of changes in the probability of trade peace on trade depends crucially on the distributions of inspection costs and productivities. A country i characterized by high inspection costs for all goods it supplies, $m_i(\omega) = \infty$, could be interpreted as an economy with low quality institutions, which lead to high contracting and enforcement costs. The solid line in Figure 5a shows the imports of country $n \neq i$, which are zero whenΨ_{ni} is low since costs are prohibitively high both under the American and the Japanese system in that case. As trade policies raise Ψ_{ni}, country i's costs of supplying under the Japanese system fall, leading to a significant rise in country n's imports as i becomes more competitive. Thus, trade under the Japanese system can be used as a way to circumvent the low quality of institutions, which prohibit trade under the American system. On the other hand, the blue dashed line presents the share of imports from country i when inspection costs are low. In this case, the country is able to export under the American system regardless of the probability of trade peace, and an increase in Ψ_{ni} has a relatively small effect on the import share. The distribution of productivities $\Upsilon_n(\omega)$ across countries and products is similarly important. If a country is significantly less productive than the other, an improvement in trade peace

Figure 5: Share of Expenditures vs. Continuation Probability (Ψ)

(a) Effect of Inspection Costs



(b) Effect of Productivity Dispersion



may not be enough to overcome the productivity disadvantage and to induce trade. On the other hand, if the variance of productivities is high across products, then a given country can be very competitive for some products but very uncompetitive for others. The red line in Figure 5b shows how a change in the probability of trade peace affects country n's imports from country i when productivities are very dispersed across products. In this case, changes in trade peace have almost no effect on trade because the productivity differences between the countries for any product are large relative to the trade peace effects. On the other hand, the blue line shows the analogous effects when the dispersion of productivities is small. In this case, all products in a given country have nearly the same productivity, and so all products that are sourced under the Japanese system switch from one country to the other at nearly the same Ψ_{ni}. The reasoning is similar for the distribution of inspection costs $m_i(\omega)$. If the variance of that distribution is low, either almost all products are shipped under the American system or almost all products are shipped under the Japanese system.

5.3 Effects of a Change in the Probability of Trade Peace

We now examine quantitatively the effects of the change in the probability of trade peace induced by PNTR on the U.S. We first discuss how we estimate the model parameters. We then simulate the model to assess the implications of PNTR. Since the model can only be solved using numerical methods, we set the number of countries to three, capturing the U.S., China, and the Rest of the World. We set a number of parameters exogenously based on existing literature and estimate the others within the model.

XXX INCOMPLETE XXX

6 Conclusion

This paper analyzes the impact of changes in trade policy on procurement patterns along a supply chain. We develop a theoretical model in which importers' ability to solve a quality control problem depends upon exporters' beliefs about the possibility of a trade war breaking out between the firms' countries. When the probability of trade peace is small, buyers choose American-style procurement, characterized by competitive bidding for large, infrequent orders, and costly inspections to ensure the provision of high-quality goods. When the probability of trade peace is high, buyers can induce sellers to provide high quality without inspections by paying them a premium above their costs over a long-term relationship. We show that changes in trade policy that reduce the likelihood of trade wars increase welfare by lowering procurement costs.

We examine the model's key implications using transaction-level U.S. import data. We begin by classifying importer-exporter relationships as American- or Japanese-style and show that these relationships differ along the dimensions – such as shipment size, shipment frequency and shipment size – emphasized in the model. Next we estimate the effect of the U.S. granting of Permanent Normal Trade Relations – which substantially reduced the possibility of a U.S.-China trade war – on the procurement patterns of U.S.-based firms. Using triple difference-in-differences specification, we show that PNTR is associated with a movement toward more Japanese-style procurement among U.S. importers and Chinese exporters along the dimensions highlighted by the model.

Our findings suggest that an important but under-examined aspect of trade agreements in a world with already low tariffs may be their affect on relationship formation. That is, trade agreements promoting institutions that allow firms to develop more stable relationships may give rise to an additional source of welfare gains from trade associated with reducing inventory and monitoring costs.[35] The extent to which such gains are smaller or larger than those that allow firms better access to contract enforcement or dispute resolution is an interesting area for further research.

[35]Indeed, improving the efficiency of trade relationships is a goal of the recent WTO agreement on trade facilitation. See https://www.wto.org/english/thewto_e/minist_e/mc9_e/desci36_e.htm.

References

Antràs, P. (2003): "Firms, Contracts, and Trade Structure," *Quarterly Journal of Economics*, 118(4), 1375–1418.

——— (2005): "Incomplete Contracts and the Product Cycle," *American Economic Review*, 95(4), 1054–1073.

Antràs, P., and E. Helpman (2008): "Contractual Frictions and Global Sourcing," in *The Organization of Firms in a Global Economy*, ed. by E. Helpman, T. Verdier, and D. Marin, pp. 9–54. Harvard University Press.

Baldwin, R. E., and J. Lopez-Gonzalez (2015): "Supply-Chain Trade: A Portrait of Global Patterns and Several Testable Hypotheses," *The World Economy*, 38(11), 1682–1721.

Baumol, W., J. Panzar, and R. Willig (1982): *Contestable Markets and the Theory of Industry Structure*. Harcourt Brace Jovanovich, New York.

Bernard, A. B., J. . B. Jensen, and P. K. Schott (2006): "Transfer Pricing by U.S.-Based Multinationals," NBER Working Paper No. 12493.

Bernard, A. B., J. B. Jensen, and P. K. Schott (2009): "Importers, Exporters and Multinationals: A Portrait of Firms in the U.S. that Trade Goods," in *Producer Dynamics: New Evidence from Micro Data*, ed. by T. Dunne, J. B. Jensen, and M. J. Roberts. Chicago University Press, Chicago.

Blaum, J., C. Lelarge, and M. Peters (2015): "The Gains from Input Trade in Firm-Based Models of Importing," mimeo.

Boehm, C. E., A. Flaaen, and N. Pandalai-Nayar (2015): "Multinationals, Offshoring, and the Decline of U.S. Manufacturing," mimeo, University of Michigan.

Cristea, A. D. (2011): "Buyer-Seller Relationships in International Trade: Evidence from U.S. States' Exports and Business-Class Travel," *Journal of International Economics*, 84(2), 207–220.

Defever, F., C. Fischer, and J. Suedekum (2016): "Relational Contracts and Supplier Turnover in the Global Economy," *Journal of International Economies*, 103, 147–165.

Dyer, J. H., and W. G. Ouchi (1993): "Japanese-Style Partnerships: Giving Companies a Competitive Edge," *Sloan Management Review*, 35(1), 51–63.

Eaton, J., and S. Kortum (2002): "Technology, Geography, and Trade," *Econometrica*, 70(5), 1741–1779.

Feenstra, R. C., and G. H. Hanson (2005): "Ownership and Control in Outsourcing to China: Estimating the Property-Rights Theory of the Firm," *Quarterly Journal of Economics*, 120(2), 729–761.

Feenstra, R. C., J. Romalis, and P. K. Schott (2002): "U.S. Imports, Exports, and Tariff Data, 1989-2001," NBER Working Paper No. 9387.

Fisman, R., and Y. Wang (2010): "Trading Favors within Chinese Business Groups," *American Economic Review: Papers & Proceedings*, 100(2), 429–433.

Grossman, G. M., and E. Helpman (2004): "Managerial Incentives and International Organization of Production," *Journal of International Economics*, 63(2), 237–262.

Han, S.-L., D. P. Wilson, and P. Dant, Shirish (1993): "Buyer-Supplier Relationships Today," *Industrial Marketing Management*, 22(4), 331–338.

Handley, K. (2014): "Exporting under Trade Policy Uncertainty: Theory and Evidence," *Journal of International Economics*, 94(1), 50–66.

Handley, K., and N. Limão (2013): "Policy Uncertainty, Trade and Welfare: Theory and Evidence for China and the U.S.," NBER Working Paper No. 19376.

Heide, J. B., and G. John (1990): "Alliances in Industrial Purchasing: The Determinants of Joint Action in Buyer-Supplier Relationships," *Journal of Marketing Research*, 27(1).

Heise, S. (2015): "Firm-to-Firm Relationships and the Cost of Recessions," mimeo, Yale.

Helper, S. R., and M. Sako (1995): "Supplier Relations in Japan and in the United States: Are They Converging?," *Sloan Management Review*, 36(3), 77–84.

Hornok, C., and M. Koren (2015a): "Administrative Barriers to Trade," *Journal of International Economics*, 96, S110–S122.

——— (2015b): "Per-Shipment Costs and the Lumpiness of International Trade," *Review of Economics and Statistics*, 97(2), 525–530.

Hummels, D., and A. Skiba (2004): "Shipping the Good Apples Out? An Empirical Confirmation of the Alchian-Allen Conjecture," *Journal of Political Economy*, 112(6), 1384–1402.

Kamal, F., C. J. Krizan, and R. Monarch (2015): "Identifying Foreign Suppliers in U.S. Merchandise Import Transactions," US Census Bureau Center for Economic Studies Paper No. CES-WP-15-11.

Kamal, F., and H. Tang (2015): "Relational Trade: Evidence from the United States," mimeograph.

Kropf, A., and P. Sauré (2014): "Fixed Costs Per Shipment," *Journal of International Economics*, 92(1), 166–184.

Kukharskyy, B., and M. Pflüger (2010): "Relational Contracts and the Economic Well-Being of Nations," IZA Discussion Paper No. 5394.

Liker, J. K., and T. Y. Choi (2004): "Building Deep Supplier Relationships," *Harvard Business Review*, 82(12), 104–113.

Lyons, Thomas F., K., A. R. Krachenberg, and J. W. Henke Jr. (1990): "Mixed Motive Marriages: What's Next for Buyer-Supplier Relations?," *Sloan Management Review*, 31(3), 29–36.

Martin, J. (2012): "Markups, Quality, and Transport Costs," *European Economic Review*, 56(4), 777–791.

Monarch, R. (2015): ""It's Not You, It's Me": Breakups in U.S.-China Trade Relationships," Federal Reserve Board, mimeograph.

Monarch, R., and T. Schmidt-Eisenlohr (2015): "Learning and the Value of Relationships in International Trade," SSRN 2594035.

O'Neal, C. R. (1989): "JIT Procurement and Relationship Marketing," *Industrial Marketing Management*, 18(1), 55–63.

Ossa, R. (2014): "Trade Wars and Trade Talks with Data," *American Economic Review*, 104(12), 4104–4146.

Pierce, J., and P. K. Schott (2016): "The Surprisingly Swift Decline of U.S. Manufacturing Employment," *American Economic Review*, 106(7), 1632–1662.

Pierce, J. R., and P. K. Schott (2012): "Concording U.S. Harmonized System Categories Over Time," *Journal of Official Statistics*, 28(1), 53–68.

Rauch, J. E. (1999): "Networks versus Markets in International Trade," *Journal of International Economics*, 48(1), 7–35.

Spencer, B. J. (2005): "International Outsourcing and Incomplete Contracts," *Canadian Journal of Economics*, 38(4), 1107–1135.

Taylor, C. R., and S. N. Wiggins (1997): "Competition or Compensation: Supplier Incentives under the American and Japanese Subcontracting Systems," *American Economic Review*, 87(4), 598–618.

Tirole, J. (1988): *The Theory of Industrial Organization.* MIT Press, Cambridge, MA.

Appendix

A Analytical Results

A.1 Proofs

A.1.1 Second Order Conditions Hold

American System The second derivative of the average cost yields

$$AC''_A(x,q) = \frac{r}{q}\frac{\left(\frac{r}{q}\right)e^{-rx/q}\frac{\bar{\theta}}{\Upsilon}\left[-2\left(1-e^{-rx/q}\right)+\left(\frac{r}{q}\right)\left[1+e^{-rx/q}\right]\left[x+\frac{f+m}{\bar{\theta}/\Upsilon}\right]\right]}{\left[1-e^{-rx/q}\right]^3}.$$

Thus the first order condition is strictly upward sloping, $AC''_A(x,q)$, if and only if

$$\left[1+e^{-rx/q}\right]\left[r\frac{x}{q}+\left(\frac{r}{q}\right)\left(\frac{f+m}{\bar{\theta}/\Upsilon}\right)\right]-2\left[1-e^{-rx/q}\right]>0. \tag{A.1}$$

Consider the case when $f+m=0$. If the condition holds for this case, it must also hold for $f+m>0$,because (A.1)is increasing in $f+m$. Define $y\equiv rx/q$. Note that for $y=0$ and $f+m=0$ the left-hand side of equation (A.1) is equal to zero. Taking the derivative of the left-hand side of equation (A.1) with respect to y we obtain

$$1-e^{-y}(1-y),$$

Thus, the left-hand side of (A.1) is strictly increasing in y for $0<y<1$. Therefore, if $0<y<1$, then $AC''_A(x,q)>0$.

Japanese System

$$\begin{aligned}AC''_J(x) = \Bigg[& \frac{\left(\frac{r}{q}\right)^2 e^{-rx/q}\left[f+\underline{\theta}\frac{1}{\Upsilon}x+e^{(r+\rho)x/q}(\bar{\theta}-\underline{\theta})\frac{1}{\Upsilon}x\right]\left[1+e^{-rx/q}\right]}{\left[1-e^{-rx/q}\right]^3} \\ & -\frac{2\left(\frac{r}{q}\right)e^{-rx/q}\left[\underline{\theta}\frac{1}{\Upsilon}+e^{(r+\rho)x/q}(\bar{\theta}-\underline{\theta})\frac{1}{\Upsilon}\left(1+\left(\frac{r+\rho}{q}\right)x\right)\right]\left[1-e^{-rx/q}\right]}{\left[1-e^{-rx/q}\right]^3} \\ & +\frac{\left(\frac{r+\rho}{q}\right)e^{(r+\rho)x/q}(\bar{\theta}-\underline{\theta})\frac{1}{\Upsilon}\left[2+\left(\frac{r+\rho}{q}\right)x\right]\left[1-e^{-rx/q}\right]^2}{\left[1-e^{-rx/q}\right]^3}\Bigg]\frac{r}{q}.\end{aligned}$$

Then $AC''_J(x)>0$, if and only if the numerator is greater than zero. Note that the numerator increases in f. Therefore if the numerator is positive for $f = 0$, it must also be positive for $f > 0$. Assume $f = 0$, and factor the numerator of $AC''_J(x)$ to obtain

$$\left(\frac{r}{q}\right) e^{-rx/q} \left[\underline{\theta}\tfrac{1}{\Upsilon} + e^{(r+\rho)x/q}(\bar{\theta} - \underline{\theta})\tfrac{1}{\Upsilon}\right] \left[\left(\frac{r}{q}\right) x \left(1 + e^{-rx/q}\right) - 2\left(1 - e^{-rx/q}\right)\right]$$
$$+ \left(\frac{r+\rho}{q}\right) e^{(r+\rho)x/q}(\bar{\theta} - \underline{\theta})\tfrac{1}{\Upsilon} \left[1 - e^{-rx/q}\right] \left\{\left[1 - e^{-rx/q}\right] \left[2 + \left(\tfrac{r+\rho}{q}\right) x\right] - 2\left(\frac{r}{q}\right) x e^{-rx/q}\right\}$$

Define $y \equiv rx/q$. For the first term note that $(1 + e^{-y})\, y - 2\,(1 - e^{-y}) > 0$ for $0 < y < 1$. For the second term to be positive, we require that $\left([1 - e^{-y}]\left[2 + y + \left(\tfrac{\rho}{q}\right) x\right] - 2ye^{-y}\right) > 0$. If $\rho = 0$, then $(\cdot) > 0$ for $0 < y < 1$. Because $(\cdot)$increases in ρ, it must be true that $(\cdot) > 0$ for $\rho > 0$ and $0 < y < 1$. Therefore, if $\rho > 0$ and $0 < y < 1$, then $AC''_J(x) > 0$.

A.1.2 Envelope Theorem

$$\left.\frac{\partial p_J}{\partial \underline{\theta}}\right|_{\underline{\theta}<\bar{\theta}} = \left[\left(e^{(r+\rho)x_J/q} - 1\right) x_J r\right] \Big/ \left[\Upsilon(e^{-rx/q} - 1)q\right] < 0$$

$$\left.\frac{\partial p_J}{\partial \bar{\theta}}\right|_{\underline{\theta}<\bar{\theta}} = x_J r e^{(r+\rho)x_J/q} \Big/ \left[\Upsilon(e^{-rx_J/q} - 1)q\right] > 0$$

$$\frac{\partial p_J}{\partial \rho} = \left(e^{(r+\rho)x_J/q} x_J^2(\bar{\theta} - \underline{\theta})r)\right) \Big/ q^2\Upsilon\left(1 - e^{-\frac{rx}{q}}\right) > 0$$

Finally, comparing procurement costs in both systems note that:

$$\frac{r}{q}\frac{f + \bar{\theta}\frac{1}{\Upsilon}x_J^* + (\bar{\theta} - \underline{\theta})\frac{1}{\Upsilon}x_J^*\left[e^{rx_J^*/q} - 1\right]}{1 - e^{-rx_J^*/q}} > \frac{r}{q}\frac{f + \bar{\theta}\frac{1}{\Upsilon}x_J^*}{1 - e^{-rx_J^*/q}} > \frac{r}{q}\frac{f + \bar{\theta}\frac{1}{\Upsilon}x_A^*}{1 - e^{-rx_A^*/q}}$$

The first inequality holds since $e^{rx_J^*/q} > 1$, the second inequality holds because the batch size that minimizes average costs in the Japanese system is strictly less than the batch size that minimizes average costs in the American system when $m = 0$,$x_J^* < x_A^*(m = 0)$. Hence, the average procurement cost under the Japanese system is strictly greater than under the American system for any $\rho \geq 0$ when $m = 0$.

A.1.3 Proof of Proposition 1

For $\bar{\theta} - \underline{\theta} > 0$ and $\rho > 0$, when $m_A = 0$ average costs under the Japanese system must be higher than under the American system by the discussion above Proposition 1. Since average costs under the American system grow without bound as $m_A \to \infty$, there must be an m^* such that average costs under the systems are equalized.

A.1.4 Proof Proposition 1

Japanese System: We apply the implicit function theorem. We obtain

$$\frac{\partial FOC_J}{\partial \rho} = \frac{2rxe^{\frac{x\rho}{q}}\left(\bar{\theta}-\underline{\theta}\right)}{q^3\Upsilon(e^{-\frac{rx}{q}}-1)}\left[\frac{x\rho}{2}\left(e^{\frac{rx}{q}}-1\right)+q\left(\left(\frac{rx}{2q}+1\right)e^{\frac{rx}{q}}-\frac{rx}{q}-1\right)\right]$$

Define $y = rx/q$. Note that $\lim_{y\downarrow 0} \left(\frac{y}{2}+1\right)e^y - y - 1 = 0$ and $\frac{d}{dy}\left(\frac{y}{2}+1\right)e^y - y - 1 = -1+\frac{1}{2}(x+3)e^x > 0$. Therefore $\frac{\partial FOC_J}{\partial \rho} > 0$. Then by the implicit function theorem

$$\frac{\partial x}{\partial \rho} = -\frac{\frac{\partial FOC_J}{\partial \rho}}{SOC_J} < 0.$$

Remember that $v_J(x_J,\rho) = f + \bar{\theta}\frac{1}{\Upsilon}x_J^* + (\bar{\theta}-\underline{\theta})\frac{1}{\Upsilon}x_J^*\left[e^{rx_J^*/q}-1\right]$. Average costs in the Japanese system are then $\frac{r}{q}\frac{v_J(x_J,\rho)}{1-exp(-\frac{rx_J}{q})}$. Taking the first order condition of these average costs and setting zero we can write.

$$\frac{\partial v(x_J,\rho)}{\partial x_J} = \frac{r}{q}\frac{v(x_J,\rho)exp(-\frac{rx_J}{q})}{1-exp(-\frac{rx_J}{q})}$$

Now take the derivative of the unit value, $\frac{v_J(x_J,\rho)}{x_J}$,with respect to ρ to obtain

$$\left(\frac{\partial v(x_J,\rho)}{\partial x_J}\frac{\partial x_J}{\partial \rho}x + \frac{\partial v(x_J,\rho)}{\rho}x_J - v(x_J,\rho)\frac{\partial x_J}{\partial \rho}\right)\frac{1}{x_J^2}$$

Substituting for $\frac{\partial}{\partial x}v(x_J,\rho)$ from the equilibrium condition (22) into (23) we can rewrite (23) to obtain

$$\left[\left(\frac{rx_J}{q}\frac{exp(-\frac{rx_J}{q})}{1-exp(-\frac{rx_J}{q})}-1\right)\frac{\partial x_J}{\partial \rho}v(x_J,\rho) + \frac{\partial v(x_J,\rho)}{\rho}x_J\right]\frac{1}{x_J^2}$$

Note that $\frac{\partial v(x_J,\rho)}{\rho}x_J = \frac{x_J^3(\bar{\theta}-\underline{\theta})}{exp(-\frac{(r+\rho)x_J}{q})q\Upsilon} > 0$. Also note that $\frac{rx_J}{q}\frac{exp(-\frac{rx_J}{q})}{1-exp(-\frac{rx_J}{q})} - 1 < 0$ for $0 < \frac{rx}{q} < 1$. Then because $\frac{\partial x_J}{\partial \rho} < 0$ we have shown that $\frac{\partial}{\partial \rho}\frac{v_J(x_J,\rho)}{x_J} > 0$

American System: We apply the implicit function theorem to show:

$$\frac{\partial x_A^*}{\partial m} = -\frac{\frac{\partial FOC_A}{\partial m}}{SOC_A} = \frac{r^2e^{-\frac{rx_A}{q}}}{q^2\left(1-e^{-\frac{rx_A}{q}}\right)^2} > 0$$

Note that unit values in the American system are simply $\frac{v_A(x_A)}{x_A} = \frac{f}{x_A} + \frac{\bar{\theta}}{\Upsilon}$.Therefore, $\frac{\partial x_A^*}{\partial m} > 0 \Rightarrow \frac{\partial \frac{v_A(x_A)}{x_A}}{\partial x_A} < 0$.

A.1.5 Proposition

Part 1: Comparing shipping sizes: $x_J^* < x_A^*$ First note that if $m = 0$ and $\bar{\theta} - \underline{\theta} = 0$, then average costs in the two procurement systems are identical. If $\frac{\partial x_A^*}{\partial m} > 0$ and $\frac{\partial x_J^*}{\partial \underline{\theta}} > 0$, then $x_J^* < x_A^*$all else equal. We apply the implicit function theorem. Let $FOC_A$and FOC_J denote the first order conditions to minimize average procurement costs, and, let $SOC_A > 0$ and $SOC_J > 0$ be the associated second order conditions that are greater than zero by (A.1.1).

American System

$$\frac{\partial x_A^*}{\partial m} = -\frac{\frac{\partial FOC_A}{\partial m}}{SOC_A} = \frac{r^2 e^{-\frac{r x_A}{q}}}{q^2\left(1 - e^{-\frac{r x_A}{q}}\right)^2} > 0$$

Japanese System

$$\begin{aligned}\frac{\partial x_J^*}{\partial \underline{\theta}} = -\frac{\frac{\partial FOC_J}{\partial \underline{\theta}}}{SOC_J} \quad &= \quad \left(\frac{r}{q}\right)\frac{1}{\Upsilon}\frac{\left[1 - e^{(r+\rho)x_J^*/q}\left[1 + \left(\frac{r+\rho}{q}\right)x_J^*\right]\right]\left[1 - e^{-r x_J^*/q}\right]}{\left(1 - e^{-r x_J^*/q}\right)^2} \\ &- \quad \left(\frac{r}{q}\right)^2\frac{1}{\Upsilon}\frac{x_J^* e^{-r x_J^*/q}\left[1 - e^{(r+\rho)x_J^*/q}\right]}{\left(1 - e^{-r x_J^*/q}\right)^2}.\end{aligned}$$

For $(r+\rho)x_J^*/q > 0$, this expression is negative if and only if

$$\frac{\left[1 - e^{(r+\rho)x_J^*/q}\left[1 + \left(\frac{r+\rho}{q}\right)x_J^*\right]\right]}{\left[1 - e^{(r+\rho)x_J^*/q}\right]} > \frac{\left(\frac{r}{q}\right)x_J^* e^{-r x_J^*/q}}{\left[1 - e^{-r x_J^*/q}\right]}. \tag{A.2}$$

Note that the left-hand side is greater than 1. Hence, we need to show that the right-hand side is less than 1. Define $y \equiv r x_J^*/q$, where $0 < y < 1$. We find for the right-hand side $\lim_{y\to 0}\frac{y e^{-y}}{1 - e^{-y}} = \lim_{y\to 0} 1 - y = 1$. Next, note that $\frac{d}{dy}\frac{y e^{-y}}{1 - e^{-y}} = \frac{e^{-y}\left[(1-y) - e^{-y}\right]}{\left[1 - e^{-y}\right]^2} < 0$. It follows that the right-hand side of (A.2) is never greater than 1. Therefore, $\partial FOC/\partial \underline{\theta} < 0$ and$\partial x_J^*/\partial \underline{\theta} > 0$.

Part 2: Comparing unit values: $v_A(x_A)/x_A < v_J(x_J)/x_J$

$$v_s(x_s)/x_s = \begin{cases} \frac{f}{x_A^*} + \frac{\bar{\theta}}{\Upsilon} & \text{if } s = A \\ \frac{f}{x_J^*} + \frac{\bar{\theta}}{\Upsilon} + \left(e^{\frac{(r+\rho)x}{q}} - 1\right)(\bar{\theta} - \underline{\theta})\frac{1}{\Upsilon} & \text{if } s = J \end{cases}$$

Comparing the expressions, $x_A^* > x_J^*$(see Part 1) and $\left(e^{\frac{(r+\rho)x}{q}} - 1\right)(\bar{\theta} - \underline{\theta})\frac{1}{\Upsilon} \Rightarrow v_A(x_A)/x_A < v_J(x_J)/x_J$.

A.1.6 Proof of Proposition 2

Part 1: Order size and shipping frequency increase in q.

American System We apply the implicit function theorem to the first order condition in the American system. From the first order condition and setting to zero we obtain $v'(x) = \frac{r(v(x)+m)e^{-rx/q}}{q\left(1-e^{-rx/q}\right)}$. Substituting this optimality condition into $\frac{\partial FOC_A}{\partial q}$we obtain

$$\frac{\partial x_A}{\partial q} = -\frac{\frac{\partial FOC_A}{q}}{SOC_A} = \frac{\left[1 - \frac{\frac{rx}{q}\mathrm{e}^{-\frac{rx}{q}}}{1-\mathrm{e}^{-\frac{rx}{q}}} - \frac{rx}{q}\right]}{SOC_A} \frac{r^2\left(v\left(x\right)+m\right)\mathrm{e}^{-\frac{rx}{q}}}{q^3\left(1-\mathrm{e}^{-\frac{rx}{q}}\right)^2}$$

Then, $0 < \frac{rx}{q} < 1 \Rightarrow [\cdot] < 0 \Rightarrow \frac{\partial x_A}{\partial q} > 0$ over the relevant parameter range where costs are positive.

For the shipment frequency, $d(x_A^*/q)/dq < 0$, define $\psi_A = x_A^*/q$. Then, simplifying the first-order condition under the American system we have

$$FOC(\psi_A) = \bar{\theta}\frac{1}{\Upsilon}\left[1 - e^{-r\psi_A}\right] - \left(\frac{r}{q}\right)e^{-r\psi_A}\left[f + m + \bar{\theta}\frac{1}{\Upsilon}q\psi_A\right] = 0.$$

Applying the implicit function theorem to this expression yields

$$\frac{\partial \psi_A}{\partial q} = -\frac{\frac{\partial FOC(\psi_A)}{\partial q}}{\frac{\partial FOC(\psi_A)}{\partial \psi_J}} = -\frac{[f+m]}{rq\left[f + m + \bar{\theta}\frac{1}{\Upsilon}q\psi_A\right]} < 0,$$

and hence the time between shipments decreases, i.e., shipping frequency increases.

Japanese System We follow the same strategy as in the proof for the American system. From the first order condition, FOC_J, we obtain $\frac{\partial v_J(x_J,q)}{\partial x_J} = \frac{rv_J(x_J,q)e^{-\frac{rx}{q}}}{q\left(1-e^{-\frac{rx}{q}}\right)}$ which we substitute into $\frac{\partial FOC_J}{\partial q}$to obtain:

$$
\begin{aligned}
\frac{\partial FOC_J}{q} &= \left[1 - \frac{rxe^{-\frac{rx}{q}}}{q\left(1-e^{-\frac{rx}{q}}\right)} - \frac{rx}{q}\right]\left(\frac{r^2 v(x,q)e^{-\frac{rx}{q}}}{q^3\left(1-e^{-\frac{rx}{q}}\right)^2}\right) \\
&- \frac{2(r+\rho)(\bar{\theta}-\underline{\theta})xre^{\frac{x\rho}{q}}}{q^4\Upsilon(e^{-\frac{rx}{q}}-1)^2}\left(\frac{x\rho}{2}\left(e^{\frac{rx}{q}}-1\right)+\left[\left(\frac{rx}{2q}+1\right)e^{\frac{rx}{q}}-\frac{rx}{q}-1\right]q\right)
\end{aligned}
$$

Note that $0 < \frac{rx}{q} < 1 \Rightarrow \left[1 - \frac{rxe^{-\frac{rx}{q}}}{q\left(1-e^{-\frac{rx}{q}}\right)} - \frac{rx}{q}\right] < 0$ & $\left[\left(\frac{rx}{2q}+1\right)e^{\frac{rx}{q}} - \frac{rx}{q} - 1\right] > 0 \Rightarrow -\frac{\frac{\partial FOC_J}{q}}{SOC_J} > 0 \Rightarrow \frac{\partial x_J^*}{\partial q} > 0$, because all other terms are positive by inspection.

To see that $d(x_J^*/q)/dq < 0$, define $\psi_J = x_J^*/q$. The first-order condition under the Japanese system can then be simplified to

$$
\begin{aligned}
FOC(\psi_J) = &\left[\underline{\theta}\tfrac{1}{\Upsilon} + \left(\bar{\theta}-\underline{\theta}\right)\tfrac{1}{\Upsilon}e^{(r+\rho)\psi_J}\left[1+(r+\rho)\psi_J\right]\right]\left(1-e^{-r\psi_J}\right) \\
&- \left(\frac{r}{q}\right)e^{-r\psi_J}\left[f + \underline{\theta}\tfrac{1}{\Upsilon}\psi_J q + (\bar{\theta}-\underline{\theta})\tfrac{1}{\Upsilon}e^{(r+\rho)\psi_J}\psi_J q\right] = 0.
\end{aligned}
\tag{A.3}
$$

Applying the implicit function theorem to this expression yields

$$
\frac{\partial \psi_J}{\partial q} = -\frac{\frac{\partial FOC(\psi_J)}{\partial q}}{\frac{\partial FOC(\psi_J)}{\partial \psi_J}}.
$$

For the numerator, we have

$$
\frac{\partial FOC(\psi_J)}{\partial q} = \frac{r}{q^2}e^{-r\psi_J}f > 0.
$$

For the denominator we find

$$
\begin{aligned}
\frac{\partial FOC(\psi_J)}{\partial \psi_J} = &(r+\rho)(\bar{\theta}-\underline{\theta})\tfrac{1}{\Upsilon}e^{(r+\rho)\psi_J}\left[2+(r+\rho)\psi_J\right]\left[1-e^{-r\psi_J}\right] \\
&+ \frac{r^2}{q}e^{-r\psi_J}\left[f + \underline{\theta}\tfrac{1}{\Upsilon}\psi_J + (\bar{\theta}-\underline{\theta})\tfrac{1}{\Upsilon}e^{(r+\rho)\psi_J}\psi_J\right] > 0.
\end{aligned}
$$

Therefore, $\partial FOC(\psi_J)/\partial q > 0$, and thus $d(x_J^*/q)/dq < 0$.

A.1.7 Lemma 1: Average cost curves are downward sloping, convex and reach a limit

Part 1: Average cost curves are downward sloping

American System The average cost function under the American system is

$$AC(q) = \frac{\theta\frac{x}{q} + \frac{f}{q} + \frac{m}{q}}{1 - exp(-\frac{rx}{q})}.$$

Taking the first derivative of the expression with respect to q, and fully writing out also the terms that involve x, we get

$$AC'(q) = \frac{-\frac{f+m}{q^2} + \theta\frac{x'(q)}{q} - \theta\frac{x}{q^2}}{1 - exp(-\frac{rx}{q})} - \frac{\frac{r}{q}exp(-\frac{rx}{q})\left[\theta\frac{x}{q} + \frac{f}{q} + \frac{m}{q}\right]x'(q)}{\left[1 - exp(-\frac{rx}{q})\right]^2} + \frac{\left(\frac{rx}{q^2}\right)exp(-\frac{rx}{q})\left[\theta\frac{x}{q} + \frac{f}{q} + \frac{m}{q}\right]}{\left[1 - exp(-\frac{rx}{q})\right]^2}.$$

Re-arranging this expression, we obtain

$$\begin{aligned} AC'(q) = & \frac{-\frac{f+m}{q^2}}{1 - exp(-\frac{rx}{q})} + \frac{1}{q}x'(q)\left\{\frac{\theta}{1 - exp(-\frac{rx}{q})} - \frac{\frac{r}{q}exp(-\frac{rx}{q})\left[\theta x + f + m\right]}{\left[1 - exp(-\frac{rx}{q})\right]^2}\right\} \\ & - \frac{x}{q^2}\left\{\frac{\theta}{1 - exp(-\frac{rx}{q})} - \frac{\frac{r}{q}exp(-\frac{rx}{q})\left[\theta x + f + m\right]}{\left[1 - exp(-\frac{rx}{q})\right]^2}\right\}. \end{aligned}$$

Note that the two terms in brackets are the first-order condition of the cost function with respect to x, which is equal to zero (this is the "Envelope condition")! This is key: because in the average cost function x and q almost always appear as x/q, we can re-arrange terms to not only cancel the expression containing $x'(q)$, but also the term involving x/q^2. Thus, we get

$$AC'(q) = \frac{-\frac{f+m}{q^2}}{1 - exp(-\frac{rx}{q})}.$$

Now, it is much easier to work with this! Also, note that this clearly shows that average cost curves are decreasing.

Japanese System The proof proceeds in the same way as before. Average costs under the Japanese system are

$$AC(q) = \frac{\theta\frac{x}{q}exp(\frac{(r+\rho)x}{q}) + \frac{f}{q}}{1 - exp(-\frac{rx}{q})}.$$

The first derivative with respect to q is (ignoring the derivative with respect to x here, which we know must be zero)

$$AC'(q) = \frac{-\frac{f}{q^2} - \theta\frac{x}{q^2}exp(\frac{(r+\rho)x}{q}) - \theta(r+\rho)\frac{x^2}{q^3}exp(\frac{(r+\rho)x}{q})}{1 - exp(-\frac{rx}{q})} + \frac{\left(\frac{rx}{q^2}\right)exp(-\frac{rx}{q})\left[\theta\frac{x}{q}exp(\frac{(r+\rho)x}{q}) + \frac{f}{q}\right]}{\left[1 - exp(-\frac{rx}{q})\right]^2}.$$

Re-arranging yields

$$AC'(q) = \frac{-\frac{f}{q^2}}{1-exp(-\frac{rx}{q})} - \frac{x}{q^2}\left\{\frac{\theta exp(\frac{(r+\rho)x}{q})\left[1+(r+\rho)\frac{x}{q}\right]}{1-exp(-\frac{rx}{q})} - \frac{\frac{r}{q}exp(-\frac{rx}{q})\left[\theta x exp(\frac{(r+\rho)x}{q})+f\right]}{\left[1-exp(-\frac{rx}{q})\right]^2}\right\}.$$

Similar to before, the term in curly brackets is the first-order condition with respect to x and is equal to zero. Therefore, we have

$$AC'(q) = \frac{-\frac{f}{q^2}}{1-exp(-\frac{rx}{q})}.$$

This function must be convex because the function under the American system was convex for all m, and thus also for $m = 0$.

Part 2: Average cost curves are convex

American System From A.1.6 we obtain the slope of the average cost curve in q :

$$AC'(q) = \frac{-\frac{f+m}{q^2}}{1-exp(-\frac{rx}{q})}.$$

Taking the second derivative of average costs then yields

$$AC''(q) = \frac{2\frac{f+m}{q^3}}{1-exp(-\frac{rx}{q})} - \frac{\left(\frac{rx}{q^2}\right)exp(-\frac{rx}{q})\left(\frac{f+m}{q^2}\right)}{\left[1-exp(-\frac{rx}{q})\right]^2} + \frac{\left(\frac{rx'(q)}{q}\right)exp(-\frac{rx}{q})\left(\frac{f+m}{q^2}\right)}{\left[1-exp(-\frac{rx}{q})\right]^2}.$$

The last term is positive since $x'(q) > 0$. Therefore, to prove that the average cost function is convex, we only need to show that the first two terms together are positive. These terms can be re-written as

$$\frac{2\left[1-exp(-\frac{rx}{q})\right]\left(\frac{f+m}{q^3}\right) - \left(\frac{rx}{q}\right)exp(-\frac{rx}{q})\left(\frac{f+m}{q^3}\right)}{\left[1-exp(-\frac{rx}{q})\right]^2},$$

which is positive if

$$2\left[1-exp(-\frac{rx}{q})\right] > \left(\frac{rx}{q}\right)exp(-\frac{rx}{q}).$$

This expression holds if

$$2\left[exp(\frac{rx}{q})-1\right] > \left(\frac{rx}{q}\right),$$

which is true. Therefore, average costs are convex, for any m and f.

Japanese System From A.1.6 we obtain the slope of the average cost curve in the Japanese system.

$$AC'(q) = \frac{-\frac{f}{q^2}}{1 - exp(-\frac{rx}{q})}.$$

By the same arguments as in the American system $AC''(q) > 0$.

Asymptote for both systems We first show $(x(q)/q) \to 0$ as $q \to \infty$.

From the Monotone Convergence Theorem, since $(x(q)/q)$ is strictly decreasing and bounded from below by zero, it must converge to a limit. Call this limit $\psi^* \geq 0$. To show that $\psi^* = 0$, assume for contradiction that $\psi^* = K > 0$. Then, it must be the case that there exists no combination of $\psi = x(q)/q < K$ and q that solves the first-order condition of the cost minimization problem. Thus, if we can find a q solving the first-order condition for a $\psi < K$, then K cannot have been the limit since ψ is strictly decreasing.

For the American system, pick any $0 \leq \psi_A < K$. The first-order condition of the cost minimization problem under the American system is

$$\bar{\theta}\frac{w_z}{\Upsilon}\left[1 - e^{-r\psi_A}\right] = \left(\frac{r}{q}\right) e^{-r\psi_A}\left[f + mw_b + \bar{\theta}\frac{w_z}{\Upsilon}q\psi_A\right].$$

Re-arranging this expression, we can solve for q as a function of ψ_A and find that

$$q = \frac{\left[f + mw_b\right] re^{-r\psi_A}}{\bar{\theta}\frac{w_z}{\Upsilon}\left[1 - e^{-r\psi_A}\left[1 + r\psi_A\right]\right]}. \tag{A.4}$$

This expression gives the q that solves the first-order condition for a given pick of $\psi_A = x_A/q$. If we can show that for any pick $\psi_A \geq 0$ there exists a $q \geq 0$ solving the equation, then it cannot be the case that $K > 0$ is the limit. For this result to hold, we need to show that the denominator is non-negative. To see that it is non-negative, note that

$$\begin{aligned} 1 - e^{-r\psi_A}\left[1 + r\psi_A\right] \geq 0 & \\ \Leftrightarrow \quad e^{r\psi_A} \geq 1 + r\psi_A&, \end{aligned}$$

which holds. Thus, for any $\psi_A \geq 0$ there exists a $q \geq 0$ solving the equation. In particular, such a q exists for any $\psi_A < K$. Therefore, $(x(q)/q)$ must converge to zero. Indeed, from the equation we can see that for $\psi_A = 0$, q must be infinite.

We can construct a similar proof for the Japanese system. The first-order condition under the Japanese system is

$$\frac{e^{(r+\rho)\psi_J}\bar{\theta}\frac{w}{\Upsilon}\left[1+(r+\rho)\psi_J\right]}{1-e^{-r\psi_J}}=\frac{\left(\frac{r}{q}\right)e^{-r\psi_J}\left[f+e^{(r+\rho)\psi_J}\bar{\theta}\frac{w}{\Upsilon}q\psi_J\right]}{\left[1-e^{-r\psi_J}\right]^2}.$$

We can re-arrange this expression to solve for q and find that

$$q=\frac{fre^{-r\psi_J}}{\bar{\theta}\frac{w_z}{\Upsilon}e^{(r+\rho)\psi_J}\left[(r+\rho)\psi_J\left[1-e^{-r\psi_J}\right]+1-e^{-r\psi_J}\left[1+r\psi_J\right]\right]}. \tag{A.5}$$

By the same argument as before, the term in the denominator is non-negative and therefore for any $\psi_J \geq 0$ there exists a $q \geq 0$ solving the equation. Therefore, $(x(q)/q)$ must converge to zero. Indeed, from the equation we can see that for $\psi_J = 0$, q must be infinite.

Convergence in the American System Consider average costs $C(x,q)/q$. Under the American system, we have that

$$\frac{C(x,q)}{q}=\frac{\theta\frac{x}{q}}{1-exp(-\frac{rx}{q})}+\frac{\frac{f}{q}+\frac{m}{q}}{1-exp(-\frac{rx}{q})}.$$

We want to show the limit of this expression goes to a positive number as $q \to \infty$. For the second term we have that

$$\lim_{q\to\infty}\frac{(f+m)\frac{x^*(q)}{q}\frac{1}{x^*(q)}}{1-exp(-r\frac{x^*(q)}{q})}=\lim_{q\to\infty}\frac{(f+m)\frac{x^*(q)}{q}}{1-exp(-r\frac{x^*(q)}{q})}\cdot\lim_{q\to\infty}\frac{1}{x^*(q)}=\lim_{\psi_A\to 0}\frac{(f+m)\psi_A}{1-exp(-r\psi_A)}\cdot 0=\frac{f+m}{r}\cdot 0,$$

by the multiplication rule of limits, where the first term converges to $(f+m)/r$ by L'Hopital's rule since $\psi_A \to 0$ as $q \to \infty$, and the second term converges to zero because $x^*(q) \to \infty$ as $q \to \infty$. Therefore, the overall term converges to 0.

For the first term we have that

$$\lim_{q\to\infty}\frac{\theta\frac{x}{q}}{1-exp(-\frac{rx}{q})}=\lim_{\psi_A\to 0}\frac{\theta\psi_A}{1-exp(-r\psi_A)}=\frac{\theta}{r},$$

where we again applied L'Hopital's rule. Therefore, overall, the average cost function under the American system converges to (θ/r), which is positive.

Convergence in the Japanese System Next consider the Japanese system. We have that average costs are

$$\frac{C(x,q)}{q} = \frac{\theta e^{(r+\rho)(x/q)}\frac{x}{q}}{1-exp(-\frac{rx}{q})} + \frac{\frac{f}{q}}{1-exp(-\frac{rx}{q})}.$$

The second term converges to zero by the same argument as before. For the first term we find

$$\lim_{\psi_J \to 0} \frac{\theta e^{(r+\rho)\psi_J}\psi_J}{1-exp(-r\psi_J)} = \lim_{\psi_J \to 0} e^{(r+\rho)\psi_J} \cdot \lim_{\psi_J \to 0} \frac{\theta \psi_J}{1-exp(-r\psi_J)} = 1 \cdot \frac{\theta}{r},$$

and hence average costs under the Japanese system asymptote to exactly the same positive limit as under the American system.

A.1.8 Proof of Proposition 4

Proof. (i) There are two effects. First, holding q fixed, Proposition 1 shows that if ρ goes down, then shipment size goes up and unit values go down. However, because a decrease in ρ shifts down the average cost curve, we also see an increase in the equilibrium quantity q. Proposition 3 shows that this increase in the equilibrium quantity further lowers unit values and further increases shipment size, so that the overall effect is unambiguous. (ii) Holding q fixed, if firms switch from the American to the Japanese system shipping frequencies and unit values increase. In equilibrium, the increase in q further increases shipping frequencies, but the unit value decreases, potentially offsetting the system-switch effect.

□

B Additional Tables and Figures

B.1 Tables

Table A.1: Simulation parameters

	Baseline
Probability of trade peace ($\Psi = e^{-\rho}$)	0.93
Order quantity (q)	1
Interest rate (r)	0.02
Low, high quality ($\underline{\theta}, \bar{\theta}$)	(0, 2)
Seller fixed cost (f)	$9 \cdot 10^{-5}$
Buyer inspection cost (m)	$4.4 \cdot 10^{-4}$

Table A.2: Classification regressions at the importer level, for $t = 15$

	(1)	(2)	(3)	(4)
Dependent Variable	ln(QPS)	ln(WBS)	ln(Price)	ln(Length)
d^A_{mhcz}	0.761***	0.847***	−0.114***	−2.261***
	(0.004)	(0.004)	(0.007)	(0.005)
$\ln(Qty_{mhcz})$	0.732***	−0.254***	−0.314***	−0.047***
	(0.001)	(0.001)	(0.002)	(0.001)
Observations	158,000	158,000	158,000	158,000
R-Squared	0.960	0.728	0.869	0.781
Fixed Effects	hc, z	hc, z	hc, z	hc, z
	(5)	(6)	(7)	(8)
Dependent Variable	ln(QPS)	ln(WBS)	ln(Price)	ln(Length)
$\ln(SPS_{mhcz})$	0.293***	0.315***	−0.031***	−0.806***
	(0.001)	(0.001)	(0.001)	(0.001)
$\ln(Qty_{mhcz})$	0.744***	−0.253***	−0.334***	−0.067***
	(0.000)	(0.001)	(0.000)	(0.000)
Observations	927,000	927,000	927,000	927,000
R-Squared	0.952	0.593	0.844	0.637
Fixed Effects	hc, z	hc, z	hc, z	hc, z

Notes: Superscripts *, **, and *** indicate statistical significance at the 10, 5, and 1 percent levels, respectively. Number of observations has been rounded to the nearest 1000 as per U.S. Census Bureau Disclosure Guidelines.

Table A.3: Classification regressions at the importer-exporter level, for $t = 15$

	(1)	(2)	(3)	(4)
Dependent Variable	ln(QPS)	ln(WBS)	ln(Price)	ln(Length)
d^A_{mhcz}	0.427***	1.307***	−0.102***	−0.195***
	(0.010)	(0.018)	(0.010)	(0.014)
$\ln(Qty_{mxhcz})$	0.555***	−0.208***	−0.108***	0.208***
	(0.002)	(0.002)	(0.002)	(0.003)
Observations	72,000	72,000	72,000	72,000
R-Squared	0.982	0.789	0.970	0.731
Fixed Effects	xhc, z	xhc, z	xhc, z	xhc, z

	(5)	(6)	(7)	(8)
Dependent Variable	ln(QPS)	ln(WBS)	ln(Price)	ln(Length)
SPS_{mhcz}	0.246***	0.531***	−0.056***	−0.121***
	(0.001)	(0.002)	(0.001)	(0.001)
$\ln(Qty_{mxhcz})$	0.637***	−0.142***	−0.140***	0.163***
	(0.000)	(0.001)	(0.001)	(0.001)
Observations	1,325,000	1,325,000	1,325,000	1,325,000
R-Squared	0.979	0.652	0.959	0.623
Fixed Effects	xhc, z	xhc, z	xhc, z	xhc, z

Notes: Superscripts *, **, and *** indicate statistical significance at the 10, 5, and 1 percent levels, respectively. Number of observations has been rounded to the nearest 1000 as per U.S. Census Bureau Disclosure Guidelines.

Table A.4: Rauch Regressions for $t = 5$ (Conservative Classification)

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent Variable	ln(VPS)	ln(WBS)	ln(Length)	ln(VPS)	ln(WBS)	ln(Length)
d_h^D	-0.192^{***}	-0.182^{***}	0.044^{***}	-0.129^{***}	-0.130^{***}	0.128^{***}
	(0.003)	(0.004)	(0.006)	(0.003)	(0.004)	(0.006)
d_h^{Ref}	-0.119^{***}	-0.109^{***}	0.045^{***}	-0.090^{***}	-0.084^{***}	0.085^{***}
	(0.004)	(0.005)	(0.007)	(0.003)	(0.005)	(0.007)
$\ln(NSupp_{mhcz})$				-0.455^{***}	-0.373^{***}	-0.608^{***}
				(0.001)	(0.001)	(0.002)
Observations	$1,556,000$	$1,556,000$	$1,556,000$	$1,556,000$	$1,556,000$	$1,556,000$
R-Squared	0.874	0.700	0.532	0.904	0.727	0.517
Fixed Effects	mc, z	mc, z	mc, z	mc, z	mc, z	mc, z

Notes: Superscripts *, **, and *** indicate statistical significance at the 10, 5, and 1 percent levels, respectively. Number of observations has been rounded to the nearest 1000 as per U.S. Census Bureau Disclosure Guidelines.

Table A.6: Frequency regression results

HS2 and product category	Dist (β_1)	SPS (β_3)	HS2 and product category	Dist (β_1)	SPS (β_3)
All	0.088***	0.499***			
	(0.001)	(0.001)			
01-05	−0.017***	0.454***	50-63	0.133***	0.418***
Animal prod.	(0.006)	(0.005)	Textiles	(0.002)	(0.001)
06-14	0.012*	0.406***	64-67	0.221***	0.438***
Vegetables	(0.007)	(0.004)	Footwear	(0.007)	(0.004)
15	0.056**	0.489***	68-70	0.111***	0.460***
Fats	(0.025)	(0.013)	Stones	(0.008)	(0.004)
16-24	0.059***	0.398***	71	0.062***	0.488***
Food	(0.006)	(0.003)	Jewelry	(0.018)	(0.014)
25-27	−0.026***	0.579***	72-83	0.081***	0.520***
Minerals	(0.011)	(0.009)	Metals	(0.003)	(0.002)
28-38	0.008	0.484***	84-85	0.111***	0.550***
Chemicals	(0.005)	(0.003)	Machinery	(0.003)	(0.002)
39-40	0.105***	0.515***	86-89	0.097***	0.525***
Plastic	(0.005)	(0.003)	Transportation	(0.006)	(0.004)
41-43	0.273***	0.466***	90-92	0.228***	0.509***
Hide	(0.007)	(0.004)	Optics	(0.006)	(0.003)
44-49	0.067***	0.441***	93-99	0.181***	0.498***
Wood	(0.005)	(0.003)	Miscellaneous	(0.006)	(0.003)

Table A.5: Import Shares in the LFTTD

HS2	Category	Avg. Import Share	HS2	Category	Avg. Import Share
01-05	Animal products	3.18%	50-63	Textiles	19.01%
06-14	Vegetables	3.29%	64-67	Footwear	4.71%
15	Fats	0.41%	68-70	Stones	1.63%
16-24	Food	4.10%	71	Jewelry	4.67%
25-27	Minerals	13.39%	72-83	Metals	7.60%
28-38	Chemicals	4.84%	84-85	Machinery	15.88%
39-40	Plastic	2.29%	86-89	Transportation	4.08%
41-43	Hide	2.20%	90-92	Optics	1.70%
44-49	Wood	2.66%	93-99	Miscellaneous	4.37%