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# Putting a Smiley Face on the Dragon: Wal-Mart as Catalyst to U.S.-China Trade

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## Abstract

Retail chains and imports from developing countries have grown sharply over the past 25 years. Wal-Mart's chain, which currently accounts for 10% of U.S. imports from China, grew 10-fold and its sales 90-fold over this period, while U.S. imports from China increased 30-fold. We relate these trends using a model in which scale economies in retail interact with scale economies in the import process. Combined, these scale economies amplify the effects of technological change and trade liberalization. Falling trade barriers increase imports not only through direct reduction of input costs but also through an expanded chain and higher investment in technology. This mechanism can explain why a surge in U.S. imports followed relatively modest tariff reductions and why Wal-Mart abandoned its "Buy American" campaign in the 1990s. Also consistent with these facts, we show that tariff reductions have a greater effect the more advanced the retailer's technology. The model has implications for the pace of the product cycle and sheds light on the recent apparent acceleration in foreign outsourcing.

**JEL Codes:** L11, L81, F12

**Keywords:** Wal-Mart, Trade, Economies of Scale, China, Technological Change, Retail Chain

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# 1 Introduction

In this paper, we study the relationship between the structure of retail markets in the U.S. and the location of manufacturing jobs. The most striking change in retail markets over the past 25 years has been an increase in the size and prevalence of “big box” chains, most spectacularly among them Wal-Mart, which has experienced a ten-fold growth in the number of stores. Imports from developing countries have also increased dramatically over this period; China’s imports to the U.S. expanded 30-fold in real terms. Wal-Mart’s imports have increased even faster: the chain now accounts for nearly 10% of U.S. imports from China, and a much larger fraction of consumer-goods imports from China. We present a theory that links these trends and show that there is a two-way relationship between the size of a dominant retailer and imports of consumer goods. The model can explain a number of observed patterns, including the concurrent and accelerating expansion of Wal-Mart and U.S. imports from China despite only modest reductions in trade barriers, and the collapse of Wal-Mart’s “Buy American” campaign in the early 1990s.

The claim has been made repeatedly in the popular press that Wal-Mart imports more than other retailers and that its purchasing patterns have influenced the location of manufacturing jobs. A 2003 Pulitzer Prize-winning series on Wal-Mart in the *Los Angeles Times* claimed that “Wal-Mart is so powerful that it moves the economies of entire countries, bringing profit and pain,” and, more specifically, that Wal-Mart “has hastened the flight of U.S. manufacturing jobs overseas” (Goldman and Cleeland (2003)). A 2004 PBS documentary focused on the “clash between the interests of Americans as workers and the desires of Americans as consumers” inherent in Wal-Mart’s “everyday low prices.”<sup>1</sup> Less ominously, the *Economist* argues that “the emergence of China as a centre of low-cost production is playing to [Wal-Mart’s] strengths” (The Economist (2004)). While other chains may also contribute to the increase in imports, we focus on Wal-Mart because it has become the

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<sup>1</sup>See <http://www.pbs.org/wgbh/pages/frontline/shows/walmart/etc/synopsis.html>.

canonical example of a large retail chain.

We model the relationship between chain size and imports as an interaction between economies of scale in retailing and economies of scale in the import process. There are two types of firms in the retail sector: a single large chain retailer with superior “chaining” technology in the form of lower costs of logistics and distribution, and many “stand-alone” (fringe) retailers. All retailers purchase their wares from competitive input markets, but the chain has a cost advantage due to scale economies in marketing. A second source of economies of scale arises because there are two input markets, one domestic and one foreign, and there is a fixed cost associated with purchasing the input from the foreign market. As a result, small retailers purchase the input domestically, at a higher cost, even when the chain purchases it offshore. These effects combine to generate an equilibrium that depends on the chain’s technological advantage, and, therefore, its size. As the chain expands, its unit input cost falls; the lower retail price increases quantity demanded. When the chain becomes sufficiently large it switches from domestic to offshore suppliers. The movement of production overseas reduces unit production cost, and increases the chain’s profit per store, giving the retailer further incentive to expand.

The relationship between these dual scale economies amplifies the effect of trade liberalization on import volume. A lower tariff not only expands imports through the usual effect on price but also causes the retailer to expand the chain. The expanded chain brings imports to more locations and reduces the retailer’s cost, causing a further expansion of the market for imports. Accounting for these additional effects due to the chain’s expansion increases the effective elasticity of demand for imports relative to standard models that only consider the direct effect of a tariff reduction. If the retailer’s chaining technology is the outcome of deliberate and costly investment lower trade barriers have an additional effect: by increasing profit per store lower trade barriers increase the chain’s optimal level of investment in the technology, which results in an even larger chain and an even greater increase in imports.

Our model can explain the observed nonlinear relationship between tariff reductions and

trade volume noted by, among others, Yi (2003), Romalis (2005), and Ruhl (2003). In the case of China, a large tariff reduction with the granting of Most Favored Nation status in 1980 had relatively little effect on exports to the U.S., while modest tariff reductions in later years have generated much larger increases in exports. The rise of Wal-Mart and other retail chains helps to resolve this puzzle: in our model, the effect of trade liberalization on import volume is greater the more advanced the retail chaining technology and the larger the retail chain.

When we generalize the model to consider many possible foreign production locations (countries), we find that the pace of technological change in the retail sector determines the pace of the product cycle. As the retailer’s technology improves production moves from location to location, either within or across countries. The “migration” of manufacturing jobs across countries induces the chain to grow even more, magnifying the chain’s effect on import volume. Because of this chain effect, trade liberalization in an importing country that affects all its (current and potential) trading partners equally can cause production to shift from one country to another. Thus, greater *potential* access to an export market can reduce a country’s exports if the same measure also increases competition from other countries. This result is consistent with the sentiment of some developing economies that industries are being lost to China (see, for instance, Moreira (2004)) over a period when U.S. import tariff rates have declined at similar rates for these countries.

Our focus on the retail chain, rather than an individual store, allows us to broaden the discussion of the impact of technological change. The technological innovations we consider — reductions in the cost of operating multi-store chains such as logistics and distribution costs — are closely tied with bar-code technology (and, more recently, radio frequency identification (RFID) technology), whose effect on store size is considered by Holmes (2001).<sup>2</sup> Because our chain store makes choices about its suppliers, it has an effect not only on the

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<sup>2</sup>Indeed, the increase in chain size in the past two decades has coincided with a sharp rise in store size (Jarmin, Klimek, and Miranda (2005)).

retail markets it serves but also on the location of manufacturing jobs and, through them, on the aggregate economy. While Wal-Mart, as the largest retail chain in the U.S. and the world, serves as the main motivation in our model, other chains have also expanded in recent decades. The expansion of these smaller retail chains has probably also contributed to the recent growth in imports (especially from China). Even in these latter cases, the relationship is likely to be driven by the same economic mechanism we highlight in this paper.

Both the expansion of the chain, which has lower prices than stand-alone retailers, and the shift of production to cheaper overseas locations expand market size. Both trends also feed on this larger market. The idea that market size affects production patterns, which dates back Adam Smith (1776), has been studied extensively in the trade literature.<sup>3</sup> We build on it using a model similar to Jones and Kierzkowski (1990) in which production is described as a set of blocks linked to form a supply chain. Outsourcing a production block entails a fixed linking cost, so the size of the market determines the extent of outsourcing.<sup>4,5</sup> In our model, the extent of outsourcing also affects the size of the market, operating through the chain store.

The remainder of this paper is organized as follows. Section 2 provides some basic facts about the recent growth of chains and imports that serve as background to our model. Section 3 describes the basic model and analyzes the effects of technological change and trade liberalization. Section 4 endogenizes the retailer's investment in chaining technology, and shows that the level of investment depends on trade policy. Section 5 analyzes the relationship between the retail chain, trade policy and the product cycle. Section 6 concludes.

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<sup>3</sup>See for example Helpman and Krugman (1985), Ethier (1979), Belassa (1967).

<sup>4</sup>See also Wan (2004) and Long, Riezman, and Souberyan (2005) for models extending this idea.

<sup>5</sup>To focus on the main issues of this paper we ignore the distinctions among the different forms these links can assume, i.e., whether the foreign producer is a subsidiary, subcontractor, or independent exporter, etc. Several recent papers have examined these contractual arrangements in more detail (see Antràs (2003), Antràs and Helpman (2004), Grossman and Helpman (2002a,b)). Of particular interest for our context is Feenstra and Hanson's (2005) study of outsourcing in China.

## 2 Background: Chains and Imports

Retail chains have grown dramatically over the past half-century, while stand-alone (“mom-and-pop”) retailers have been declining. A recent study of establishment-level data from the Census Bureau covering the period 1975-2000 shows that retail chains were the driving force behind the growth in the number of retail stores and the sole source of growth in retail employment over this period. Among retail chains, national chains grew the fastest (Jarmin, Klimek, and Miranda (2005)).

Table 2 shows the increase in the size and dominance of chains over the period 1948-1997. In the first three columns we compute, respectively, the fraction of retail firms that operate chains, the share of all retail stores that belong to chains, and chains’ share of all retail sales. All three measures rise over time, with a distinct rise in the share of chain stores since the early 1970s. In the last three columns we compute the same three measures but for large chains (with 100 or more stores) relative to all chains; large chains have been gaining market share relative to smaller chains throughout this period.

This trend may be explained by advances in technology that increasingly raise chains’ cost advantage over stand-alone retailers. Although available measures of productivity and efficiency for the retail industry are relatively poor, chains appear to be more productive than stand-alone retailers and they invest more in information technology (IT) (Doms, Jarmin, and Klimek (2004)). Foster, Haltiwanger, and Krizan (2002) show that the bulk of productivity growth in the U.S. retail sector in the 1990s came from the expansion of more-productive retail chains and the contraction and exit of less-productive retailers, and that the retail sector exhibits large and persistent productivity differences across establishments within narrow (4-digit) industries.

Wal-Mart is the largest retail chain in the United States (and the world). The chain has expanded steadily since opening its first store in Rogers, Arkansas, in 1962; by 2004, it had more than 3000 stores in all 50 states and about 800,000 employees in the U.S., and accounted for 7% of all U.S. retail sales. Figure 1 shows U.S. Wal-Mart sales in real 2002

dollars over the period 1978-2004 as a thick-set line (using the right-hand axis). Figure 2 separates Wal-Mart's sales growth since 1985 into two components: the rise in the number of Wal-Mart stores (solid line, left axis) and sales per store (dotted line, right axis). Since part of the growth in sales per store has been fueled by the rise of the "Supercenter" format which includes a full line of groceries, we also compute, starting in 1997, sales per store excluding grocery sales.<sup>6</sup>

Wal-Mart's technological prowess, its zealous cost-cutting, and its propensity to import have all received much attention in popular discourse. Feiner, O'Andraia, Black, Jones, and Konik (2002) cite Wal-Mart's "use of technology for merchandising, distribution and replenishment" as its main advantage over other retailers (p. 217). A study by McKinsey Global Institute (2001) attributes much of the acceleration in productivity growth in the 1990s to Wal-Mart, and Holmes (2001) and Bagwell, Ramey, and Spulber (1997) also cite evidence that Wal-Mart is a leading investor in IT. In 1990, Wal-Mart introduced a technological innovation, Retail Link: software connecting its stores, distribution centers, and suppliers, providing detailed inventory data "to bring our suppliers closer to our individual stores" (Wal-Mart Stores, Inc., 1991, p. 3). Many industry observers credit Wal-Mart's subsequent dominance in the retail sector to this innovation (see, for example, Abernathy, Dunlop, Hammond, and Weil (1999)).

While Wal-Mart's main advantage over its rivals appears to be in logistics and distribution (in the language of our model, it has a superior "chaining" technology), it also benefits, like other chains, from a lower effective unit input cost. Most small retailers make their purchases of national brands through intermediaries, either traditional wholesalers or manufacturers' representatives. Wal-Mart and other retailers that handle large quantities enjoy economies of scale because they can purchase directly from manufacturers. Although manufacturers are required to sell at the same price to all their customers, in practice large

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<sup>6</sup>The share of sales due to groceries has been reported since 1997 in Wal-Mart's 10-K filings.



retailers pay lower unit input costs. One common mechanism that generates these lower costs is manufacturers' practice of "reimbursing" large buyers for marketing expenses the retailers incur to promote their products. Our impression from conversations with retail industry insiders is that these payments depend more on the number of units a retailer sells than on any actual costs incurred; the per-unit "reimbursement" increases with the size of the retailer. There is much anecdotal evidence that Wal-Mart's unit input costs have been declining over time; the magazine *Fast Company* reported in 2003 that for "basic products that don't change, the price Wal-Mart will pay, and will charge shoppers, must drop year after year" (Fishman (2003)). While there are other possible explanations for this policy, lower transactions costs provide an economically-plausible explanation that is consistent with increased sales volume.

In 1985, Wal-Mart launched a popular and well-publicized "Buy American" campaign, pledging to "buy American whenever we can," and to pay up to a 5% premium for U.S.-made goods (Zellner (1992)). In late 1992, however, Dateline NBC aired a segment charging that Wal-Mart was producing private-label clothes in Bangladesh, smuggling Chinese garments into the U.S. in excess of U.S. quotas, and placing imported clothes on racks marked "Made in the USA" (Gladstone (1992)). References to the "Buy American" campaign disappeared from both the popular press and Wal-Mart's publications by early 1993.<sup>7</sup> In the context of our model, Wal-Mart's abandonment of its "Buy American" campaign can be attributed to its expansion over the course of the campaign from 859 to 1880 stores, possibly passing a pass a threshold size beyond which purchasing inputs domestically was no longer profit maximizing.

Concurrent with Wal-Mart's expansion, U.S. imports from the rest of the world, and

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<sup>7</sup>Wal-Mart referred to its "Buy American" campaign as "a key philosophy of our buying divisions" in its 1987 annual report (p. 8), and reiterated its commitment to "'Buy American' in every possible situation" in the 1989 annual report (p. 2). By 1994, the annual report stated (p. 6), "We wish that everything we sell was made in the United States. Today this isn't possible, but we are going to keep trying" (Wal-Mart Stores, Inc. (various years)).

from less-developed countries (LDCs) in particular, have surged. Between 1984 and 2004, U.S. imports from China increased more than 30-fold in real terms. Imports from China are shown in Figure 1 as a thin solid line, using the right-hand axis, on the same scale as U.S. Wal-Mart sales.<sup>8</sup> The emergence of “private label” (store-brand) apparel that competes directly with U.S. apparel manufacturing, and global sourcing of apparel production, also coincided with these trends (Gereffi (1999)). This rise in imports has occurred while import tariffs on Chinese goods have fallen only modestly. The only sharp decline occurred in 1980, when China was granted Most Favored Nation (MFN) status with the U.S.; since then, tariffs on Chinese goods have fallen gradually, as part of the general reduction in MFN (now Normal Trade Relations) rates. The dotted line in Figure 1 shows, on the left-hand axis, the average (unweighted) U.S. tariff rate applicable to products exported from China for the period 1978-2000.<sup>9</sup>

Many observers have speculated on a link between these concurrent trends in the retail and import sectors. Early on, Wal-Mart and a few other retailers provided the only link between Asian manufacturers and the American market (Petrovic and Hamilton (2005)); Gereffi (1999) argues that the growth of “high volume, low cost discount chains,” including Wal-Mart, has amplified global sourcing (pp. 44-45). Wal-Mart’s import volume is not publicly available, but some figures have been cited in the popular press. Lahart (2005) reports that Wal-Mart accounted for approximately \$18 billion in goods imports from China in fiscal 2004 implying that Wal-Mart alone is responsible for roughly 10% of U.S. imports from China; about half of this amount refers to direct imports, the rest coming through its suppliers (The Economist (2004)).<sup>10</sup> Others estimate that 80% of Wal-Mart’s global

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<sup>8</sup>This figure uses the finished-goods Producer Price Index to deflate nominal import values from the U.S. Bureau of Economic Analysis. The true growth rate is probably even larger, because the composition of imports from China is skewed towards items, like apparel and toys, whose prices have been falling relative to the overall price level.

<sup>9</sup>We thank John Romalis for providing these data from Romalis (2005). Figures for 2001-2004 are not available but do not include any sharp breaks.

<sup>10</sup>Since a large share of U.S. imports from China are intermediate goods, Wal-Mart’s share of consumer goods’ imports is substantially higher.

suppliers are located in China (Goodman and Pan (2004)), and that 70% of its products are made in China (Jiang (2004)).<sup>11</sup>

A look at the relationship between apparel price inflation and Wal-Mart’s market share also suggests that Wal-Mart imports disproportionately more than other apparel sellers. Using annual data on consumer price inflation in the apparel sector for 23 metropolitan areas ( $\Delta P_{it}$ , with  $i$  indexing the location and  $t$  indexing year), import price inflation at the national level ( $\Delta P_t^m$ ), and Wal-Mart’s market share ( $WMshare_{it}$ ) over a 19-year period, we estimate

$$\Delta P_{it} = \beta_1 + \beta_2 \Delta P_t^m + \beta_3 WMshare_{it} + \beta_4 \Delta P_t^m \cdot WMshare_{it} + \varepsilon_{it}. \quad (1)$$

The results are shown in Table 1 for two different measures of import price inflation.<sup>12</sup> For each measure, we report in the first column results from regressions include only import price inflation (no covariates); we find a positive and statistically significant relationship between the two inflation rates: 1-point increase in apparel import price inflation corresponds to a 0.4-0.5 point increase in apparel consumer price inflation. In the second column, we add Wal-Mart’s market share and the interaction term. The direct effect of Wal-Mart is to reduce apparel inflation, consistent with the common perception that Wal-Mart’s presence serves as a discipline device for costs.<sup>13</sup> The coefficient on the interaction term is positive: increasing Wal-Mart’s market share from 1% to 2% — an increase of 10 stores, on average — nearly doubles the sensitivity of consumer price inflation to import price inflation. Such an effect implies that the import share of apparel sales at Wal-Mart stores is substantially higher than at the average apparel retailer.<sup>14</sup>

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<sup>11</sup>This last figure is almost certainly exaggerated, but the increase in the chain’s import share of sales is not disputed.

<sup>12</sup>The data are described in full in Appendix B.

<sup>13</sup>As noted by Hausman and Leibtag (2004), the BLS’s correction for sampling changes biases the indices *against* exhibiting a “Wal-Mart effect.”

<sup>14</sup>Wal-Mart’s market share is measured with error, since the number of stores in the denominator is not weighted by their sales share, and we do not control for the existence of other large chain retailers which may also import disproportionately to their size. These problems bias us *against* finding an effect, however, so the estimated effect is probably a lower bound on the effect of large chains on apparel imports.

These results are not definitive, but they are strongly suggestive that Wal-Mart’s presence is associated with a higher level of imports in an MSA, and they are consistent with the common perception that Wal-Mart acts as a catalyst to greater imports and increased global sourcing. In the next section, we suggest a mechanism that can generate this effect.

## 3 Model

### 3.1 Domestic Production

Our basic model has two sectors: a retail sector and a manufacturing sector. We describe each in turn.

There are  $N$  locations or retail markets ( $N$  large), which are *ex ante* identical. Each location is served by a monopolist retailer selling a single consumption good.<sup>15</sup> Market demand in each location,  $x$ , is downward-sloping with demand at  $p = 0$  equal to  $\bar{x} < \infty$ . The price charged by the monopolist in market is constrained by potential entrants who can enter costlessly and instantaneously.

We assume that most retailers, including all potential entrants, can only operate stand-alone stores.<sup>16</sup> There exists one retailer with access to “chaining technology”: this retailer can operate a chain of  $k \geq 1$  stores at a cost  $\frac{c(k)}{\delta}$  if  $k > 1$ , where  $\delta > 0$  is a technology parameter and  $c(\cdot)$  is increasing and convex.<sup>17</sup> We think of  $c(k)$  as capturing the costs of adding truck routes, distribution center inventory, etc.; access to this technology is the only exogenous difference between the chain and other retailers. The motivation for a positive second derivative on  $c(\cdot)$  is that each additional store is accommodated by re-optimizing distribution facilities, inventory management and trucking routes, and this process becomes

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<sup>15</sup>The assumption that retailers are local monopolists is only for convenience. Bertrand competition among two retailers in a single location would achieve the same outcome.

<sup>16</sup>This is consistent with the recent Censuses of Retail Trade, which shows that 95% or more of U.S. retailers operate a single establishment (store). See Table 2.

<sup>17</sup>Formally,  $c(1) = c'(1) = 0$ ,  $c' > 0$  for  $k > 1$ ,  $c'' > 0$ .

increasingly complex — and costly — as the network expands.<sup>18</sup> In addition, without convex chaining costs, nothing would keep the chain from expanding to take over all retail locations; this scenario is both unrealistic and uninteresting from our point of view. The technology parameter  $\delta$  captures Wal-Mart’s advantage over other retailers in chaining technology: if  $\delta$  is very high, then the cost of chaining is very low. We begin by treating  $\delta$  as exogenous; we later endogenize it to capture the retailer’s investment decision.<sup>19</sup>

The retailer’s role is to buy the consumption good from a manufacturer or wholesaler and sell it to consumers. The retailer’s unit input cost consists of two elements: the consumption good’s “free on board” (FOB) price and a marketing cost.<sup>20</sup> The consumption good is produced by a competitive market using a constant-returns production technology with marginal cost  $\alpha$ . Retailers also need to incur a marketing cost to sell their products. Each retailer has access to two marketing technologies, one linear and one convex. For a retailer with  $k \geq 1$  stores, each of which sells  $x \geq 0$  units, the linear technology has total marketing cost  $h k x$  where  $h > 0$  is a constant. Alternatively, retailers can use a convex marketing technology; this alternative has total cost of  $S(kx) > 0$ , with  $S(\cdot)$  increasing but concave. Since retailers choose the lower-cost option for a given  $(k, x)$ , the effective marketing cost is  $\min\{h k x, S(kx)\}$ . The two technologies are depicted graphically in Figure 3. We define  $z$  implicitly by  $h z = S(z)$ , so a retailer uses the linear technology iff  $k x \leq z$ , and the convex technology otherwise. We assume that  $z > \bar{x}$  where  $\bar{x} < \infty$  is the quantity demanded in a single location if  $p = 0$ .<sup>21</sup> The linear technology, with the condition on  $z$ , ensures that

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<sup>18</sup>Holmes (2005) explicitly models the expansion pattern of Wal-Mart, with a focus on “economies of density” — the cost-savings achieved when stores are located near one another. We abstract from that issue here, treating all locations as symmetric with respect to one another.

<sup>19</sup>Allowing only one retailer to have access to chaining technology enables us to focus on the role of a single chain in the import process, while simplifying the constraints in the chain’s optimization problem below. Alternatively, other retailers may have the same technology but values of  $\delta$  small enough to preclude chaining (operating more than one store).

<sup>20</sup>Our analysis would not change if retailing technology involved two or more inputs, used in fixed proportions, if those inputs were supplied by a competitive market. We do, however, abstract from any cost advantages the chain may have in other inputs.

<sup>21</sup>This implies that  $S'(0) > h$ , i.e., that for small  $kx$  the convex technology has higher marginal cost than

small retailers have  $MC = AC$  and so make zero profit by charging the competitive price. Because  $z > \bar{x}$ , only the chain has a potential for declining marginal cost.<sup>22</sup>

Combining the production and marketing components, the total input cost for a retailer of size  $k$  is  $\alpha kx + \min\{h kx, S(kx)\}$ . Since a stand-alone retailer maximizes profit in a single location, where demand can never be large enough to justify the convex marketing technology, its minimized cost is  $x(\alpha + h)$ . The contestable-market assumption implies that a stand-alone retailer cannot charge a price above  $(\alpha + h)$ ; let  $x_s > 0$  be demand at  $p = \alpha + h$ .

The chain retailer faces a more complex problem: it must simultaneously choose its size (number of stores) and quantity (equivalently, price) in each location. Formally, it solves

$$\begin{aligned} \max_{k,x} \quad & \pi(k, x) = kx(p(x) - \alpha) - \min\{h kx, S(kx)\} - \frac{c(k)}{\delta} \\ \text{subject to} \quad & k \in [1, N] \\ & x \geq 0 \\ & p(x) \leq \alpha + h \end{aligned} \tag{2}$$

where  $p(x)$  is the inverse demand function. The first constraint is on chain size, which cannot fall below 1 and cannot exceed the total number of locations in the economy.<sup>23</sup> The second constraint is on the number of units sold per store, which cannot be negative. The third constraint is the contestable-market constraint: the chain retailer cannot charge a price higher than a potential (stand-alone) entrant would charge. To simplify this problem, we

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the linear technology. Also,  $S'(z), h$ , so a retailer's marginal cost falls discretely when the chain reaches the threshold size  $z$ .

<sup>22</sup>As an empirical observation, small retailers tend to purchase through intermediaries while large retailers tend to be vertically integrated. Consistent with this observation, Basker (2005a) finds that the opening of a new Wal-Mart store is associated with an increase in retail employment but a decrease in wholesale employment at the county level.

<sup>23</sup>Since  $c(1) = c'(1) = 0$ , the chain can always emulate a stand-alone retailer and earn zero profit. For the most part, we assume that the upper limit  $N$  on  $k$  does not bind. This seems reasonable as a first approximation: although Wal-Mart currently has more than 3,000 stores in the U.S. alone, its expansion plan suggests there is plenty more room for it to grow. Wal-Mart's plans for 2005 include opening at least 120 new stores (Wal-Mart Stores, Inc. (2004)). We also ignore integer problems in the solution  $k^*$ .

redefine  $p(x)$  to be the inverse *residual* demand function at a location, replacing  $p(x) = \alpha + h$  for  $x \leq x_s$ , where  $x_s$  is quantity demanded at  $p = \alpha + h$ .

Using this transformation, if a solution  $(k^*, x^*)$  exists with  $k^* \cdot x^* \leq z$ , it will satisfy the first-order conditions

$$x \cdot (p(x) - \alpha - h) - \frac{c'(k)}{\delta} = 0 \quad (3)$$

$$k \cdot (p'(x)x + p(x) - \alpha - h) = 0. \quad (4)$$

Equations (3) and (4) have a unique solution,  $(k^*, x^*) = (1, x_s)$ . This solution guarantees zero profit because the chain is emulating a stand-alone retailer with the same cost and revenue.

Alternatively, if an interior solution  $(k^*, x^*)$  exists such that  $k^* \cdot x^* > z$  — i.e., the chain is large enough to use the increasing-returns marketing technology — it must satisfy the first-order conditions

$$x \cdot (p(x) - \alpha - S'(kx)) - \frac{c'(k)}{\delta} = 0 \quad (5)$$

$$k \cdot (p'(x)x + p(x) - \alpha - S'(kx)) = 0. \quad (6)$$

This interior solution dominates  $(k, x) = (1, x_s)$  if and only if it yields a positive profit. We show the second-order conditions for an interior solution and derive sufficient conditions for existence and uniqueness of the solution in Appendix A.

We write the global solution to Equations (3) and (5) as  $k^*(x)$ , and the global solution to Equations (4) and (6) as  $x^*(k)$ . Figure 4 shows the determination of  $x^*(k)$ . The marginal revenue line is shown as two thick-set segments. The first, horizontal at  $p = \alpha + h$ , shows that marginal revenue is constant for  $x \leq x_s$ ; the second segment is downward sloping, since a retailer selling more than  $x_s$  units faces a downward-sloping demand curve. (The demand curve shown is  $p = a - bx$ .) A family of marginal cost curves is shown as thin lines, each

for a different value of chain size,  $k$ . Since the linear marketing technology is more efficient if and only if  $x < \frac{z}{k}$ , each marginal cost curve has two segments: for  $x < \frac{z}{k}$ , marginal cost is constant at  $\alpha + h$ ; and for  $x \geq \frac{z}{k}$ , marginal cost is declining,  $\alpha + S'(kx)$ . Since  $S' > 0$  and  $S'' < 0$ , increasing  $k$  rotates the marginal cost curve clockwise around  $\alpha + S'(0)$ . The threshold value  $\bar{k}$  is defined as the highest value of  $k$  for which  $x^*(k) = x_s$ , i.e., sales per store are still constrained by potential entrants.<sup>24</sup> We assume that  $\bar{k} < N$ , where  $N$  is the total number of locations. Graphically, at  $\bar{k}$ , the marginal cost curve  $\alpha + S'(\bar{k}x)$  crosses the top of the downward-sloping segment of the marginal revenue curve. For all higher values of  $k$ , such as  $k_2 > \bar{k}$  in the figure,  $x^*(k) > x_s$  and price is below  $\alpha + h$ .

Since  $(k^*, x^*) = (1, x_s)$  guarantees zero profit, the chain chooses the interior solution only if it yields positive profit. Whether the corner or interior solution dominates depends on the technology parameter  $\delta$ ; the solution is unique in all but a knife-edge case. Figures 5 and 6 show, for two different values of  $\delta$ , the simultaneous determination of  $(k^*(x), x^*(k))$ . In each figure, the curve  $k^*(x)$  is shown as the thick-set solid line and  $x^*(k)$  as the thin solid line. The hyperbola  $kx = z$  marks the boundary above which  $k^*(x)$  is given by Equation (5), and below which it is given by Equation (3).

The curve  $k^*(x)$  shows the optimal chain size for every possible value of  $x$ , the number of units sold per store. If  $x$  is small, the chain has to be very large to enjoy the scale economies derived from the convex marketing technology; but a larger chain size is associated with a large (and increasing) chaining cost. Thus for small values of  $x$  the optimal chain size is  $k^* = 1$ . As  $x$  increases, the chain size  $k$  needed to switch to the convex marketing technology falls, and eventually justifies the chaining cost  $\frac{c(k)}{\delta}$ .

The thinner curve  $x^*(k)$  shows the optimal number of units sold per store for every possible chain size  $k \in [1, N]$ . If  $k$ , the chain size, is small,  $x^*(k) = x_s$ : the chain sells the same number of units per store (at the same retail price) as a stand-alone store. For small  $k$ ,

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<sup>24</sup> $\bar{k}$  solves  $S'(\bar{k}x_s) = h + p'(x_s)x_s$  where  $p'(x_s)$  refers to downward-sloping segment of the demand curve.



marginal cost and marginal revenue associated with an increase in  $x$  are both  $\alpha + h$  because the linear marketing technology is more efficient than the convex marketing technology. As  $k$  increases, the convex marketing technology becomes optimal, and the chain's marginal cost falls below  $\alpha + h$ ; however, for  $k \leq \bar{k}$ , marginal revenue remains  $\alpha + h$  because potential entry by stand-alones constrains the chain's monopoly price. Only for  $k > \bar{k}$  does  $x^*(k)$  start increasing beyond  $x_s$ . Note also that  $\bar{k} > \frac{z}{x_s}$ : at  $k = \frac{z}{x_s}$ , the chain switches from the linear to the convex marketing technology, and begins to earn an operating profit per store, but the price constraint imposed by potential entrants still binds.

Figure 5 depicts the case where  $\delta$ , the chain's technology parameter, is low, so the cost of operating multiple stores is high. As a result,  $k^*(x) = 1$  for a large set of possible values of  $x$ . The unique equilibrium in this case is the corner solution  $(k^*, x^*) = (1, x_s)$ : the chain operates a single store, emulating a stand-alone and earning zero profit. In Figure 6,  $\delta$  is higher; this parameter change does not alter the curve  $x^*(k)$ , but it affects  $k^*(x)$  in two ways: it reduces the range of  $x$  for which the corner solution  $k^*(x) = 1$  dominates, and it rotates the curve  $k^*(x; \delta)$  satisfying the interior first-order condition (Equation (5)) clockwise, increasing the optimal value of  $k$  for values of  $x$  where  $k^*(x) > 1$ . The new equilibrium features a higher  $k^*$  as well as a higher  $x^*$ : the chain operates multiple stores and sells more units per store (at a lower retail price) than would a stand-alone store.

Let  $(k^*(\delta), x^*(\delta))$  be the (global) solution to the chain's optimization problem for a given value of  $\delta$ , and define  $\delta_c$  to be the smallest value of  $\delta$  for which the retailer operates a chain: i.e., the value of  $\delta$  at which interior solution generates zero profit. We show in Appendix A that for  $\delta > \delta_c$ ,  $\frac{dk^*}{d\delta} > 0$  and  $\frac{dx^*}{d\delta} > 0$ . This implies that the chain's retail price  $p(x)$  falls when  $\delta$  increases, while the chain's total value of sales — measured as  $kxp(x)$  — increases.

There is much evidence that Wal-Mart's chaining technology has improved over time. In 1969, the company installed a computer in its first distribution center; by the late 1970s a computer network linked all Wal-Mart stores and distribution centers to company headquarters. Bar-code technology was added in all distribution centers by the late 1980s (Feiner,

O’Andraia, Black, Jones, and Konik (2002)). If  $\delta$  increases slowly over time, starting from a low level, the retailer operates a stand-alone until its size increases discretely at  $\delta_c$ . As the firm’s technology parameter increases beyond  $\delta_c$  its optimal size continues to increase. The fact that chain size increases in  $\delta$  only once the retailer’s chaining technology has passed some threshold value implies that even if many retailers had access to some chaining technology, with a continuous distribution of  $\delta$ , the observed mass point at  $k = 1$  (see Table 2) would remain.

### 3.2 Foreign Production

We now suppose that the consumption good can be manufactured either domestically or offshore (and imported) and derive both the conditions under which the chain chooses to import the good and the consequences of this choice.

Assume for simplicity that there are two possible production locations (domestic and foreign); we allow for a continuum of possible production locations in Section 5. In each location there is a large number of identical manufacturers with a constant-returns production technology, and pricing is competitive. We now write the domestic manufacturing sector’s competitive price as  $\alpha_0$ . The foreign manufacturing sector has lower marginal cost (and therefore FOB price)  $\tilde{\alpha}_1 \ll \alpha_0$ , but there is a transportation cost (normalized to zero for the domestically-produced good) and tariff that sum to  $\tau$  per unit. We define  $\alpha_1 \equiv \tilde{\alpha}_1 + \tau < \alpha_0$  to be the marginal cost of production and delivery (exclusive of marketing) if the good is produced offshore.

In addition to the production and transportation cost/tariff, a retailer purchasing input from a foreign manufacturer must pay a positive fixed cost  $F$ . This fixed cost includes the cost of setting up a production facility or a relationship with a producer in a foreign country, or a network of buyers such as the one that Wal-Mart has in China, and possibly

any non-pecuniary costs such as backlash from domestic residents.<sup>25</sup> We assume that the retailer, and not the manufacturer, bears the cost  $F$  for several reasons. First, as mentioned earlier, approximately 50% of Wal-Mart's imports are direct imports through its contracts with foreign manufacturers. In these cases, it seems reasonable to assume that Wal-Mart bears any fixed cost.<sup>26</sup> In a careful micro-level analysis of trading firms, Bernard, Jensen, and Schott (2005) note that an increasing number of U.S. firms that trade (import and/or export) are concentrated in the retail and wholesale sectors rather than the goods-producing sector; Gereffi (1999) also notes the increasing role of retailers in global sourcing. It is also possible to view the media backlash against Wal-Mart following the publicity about its high import volume as a non-pecuniary fixed cost. Finally, a competitive sector with constant marginal cost could not survive in the presence of fixed costs of setup unless this cost is borne by the retailer.

To capture the retailer's additional choice variable we introduce the variable  $\theta \in \{0, 1\}$ , which equals 0 if the input is purchased from domestic producers, or 1 if the input is imported. Cost-minimization implies that the chain purchases the input domestically when  $kx < \frac{F}{\alpha_0 - \alpha_1}$  and imports it from offshore producers when  $kx \geq \frac{F}{\alpha_0 - \alpha_1}$ . We assume that stand-alone stores cannot be large enough to meet the condition for importing even if their input demand is aggregated by a wholesaler.<sup>27</sup> This implies that the contestable-market constraint remains  $p \leq \alpha_0 + h$  regardless of the chain's input source. The marketing cost is independent of the production location.

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<sup>25</sup>Swenson (2005) offers evidence from the U.S. Offshore Assembly Program (OAP) suggesting that the pattern OAP outsourcing is consistent with the presence of a fixed cost, which she attributes to search and product development.

<sup>26</sup>An estimated 40% of Wal-Mart's revenue comes from its store brands (Petrovic and Hamilton (2005)).

<sup>27</sup>Because we want to highlight the role that a single chain can play in the import process, we abstract away from the possibility that a wholesaler can aggregate demand from multiple small stores and contract with a foreign producer. Such a wholesaler would simply function as an additional chain. We discuss the consequences of allowing multiple chains in our concluding remarks.

The chain's maximization problem becomes

$$\begin{aligned}
& \max_{k,x,\theta} \quad \pi(k,x,\theta) = kx(p(x) - (1-\theta)\alpha_0 - \theta\alpha_1) - \min\{hkkx, S(kx)\} - \frac{c(k)}{\delta} - \theta F \\
& \text{subject to} \quad k \in [1, N] \\
& \quad \quad \quad x \geq 0 \\
& \quad \quad \quad \theta \in \{0, 1\}.
\end{aligned}$$

We omit the constraint that  $p \leq \alpha_0 + h$  because we have redefined  $p(x)$  so that demand is zero for higher prices. Since the choice of  $\theta$  is discrete, to solve this problem the chain compares its maximized profit if it purchases the input from domestic suppliers with profit from the alternative case in which it purchases the input from foreign manufacturers. If  $\theta = 1$ , i.e., if the chain imports the input, it always uses the convex marketing technology. Letting  $(k_\theta^*, x_\theta^*)$  be the *conditional* optimum  $(k^*, x^*)$  for a given  $\theta$ , the chain compares  $\pi(k_0^*, x_0^*, 0)$  and  $\pi(k_1^*, x_1^*, 1)$ ; the choice of  $\theta$  depends on whether the increase in profit from obtaining a lower-price input fully offsets the fixed cost of importing  $F$ . For  $\theta = 0$ , the solution is identical to the case solved above, with only domestic suppliers available. The solution if  $\theta = 1$  is nearly identical (using  $\alpha = \alpha_1$ ), with the exception that the contestable-market constraint imposed by potential entry of stand-alone retailers uses  $\alpha_0$ , the (higher) domestic input price, even if the chain retailer purchases input abroad for a lower marginal cost.

The solution is shown graphically in Figure 7. An interior solution  $(k_0^*, x_0^*)$  is shown at the intersection of the solid thick-set and thin curves representing  $k_0^*(x; \delta)$  and  $x_0^*(k)$ . The alternative solution  $(k_1^*, x_1^*)$  is shown at the intersection of the dashed thick-set and thin lines. Because  $\alpha_1 < \alpha_0$ , if the input is imported the chain does not need to be large enough to use the convex marketing technology in order to be profitable: it earns a positive variable profit per store even if  $k = 1$ . Therefore, conditional on  $\theta = 1$  (and therefore a sunk cost  $F$ ), for any level of sales per store  $x > 0$  the chain chooses a chain size  $k > 1$ : an importing retailer always has multiple stores. For  $x < x_s$ , price does not fall as  $x$  increases because

the contestable-market constraint binds, so increasing  $x$  unambiguously increases profit per store, and therefore increases the optimal size of the chain. For every value of  $x$  the chain weighs the advantage of increasing its size to  $k > \frac{z}{x}$ , at which point it can benefit from the more efficient convex marketing technology (but pay the higher chaining cost associated with the larger chain size  $k$ ), against the alternative of keeping  $k$  low and using the linear marketing technology. Because the chain's marginal cost is lower when it uses the foreign input, the threshold value of  $x$  at which the chain sets  $k > \frac{z}{x}$  — and switches to the convex marketing technology — is lower than in the case where the chain purchases its input from domestic suppliers.

The curve  $x^*(k)$  also depends on  $\theta$ , because the threshold value  $\bar{k}$  (at which the contestable-market constraint stops binding) falls when the chain imports the input. For low values of  $k$ , the chain optimally choose  $x^*(k) = x_s$  regardless of the input source; but for  $k$  sufficiently high,  $x_1^*(k) > x_0^*(k)$ .<sup>28</sup>

We start by establishing that the optimal chain size conditional on the chain purchasing input from offshore producers is larger than the optimal chain size conditional on its purchasing input from domestic producers.

**Lemma 1.**  $k_1^* \geq k_0^*$ , and  $k_1^* > k_0^*$  except when  $k_0^* = N$ .

All proofs are in Appendix A.

Let

$$G(\alpha_1, \delta) \equiv \pi(k_1^*, x_1^*, 1; \alpha_1, \delta) + F - \pi(k_0^*, x_0^*, 0; \delta) \quad (7)$$

be the difference, net of the fixed cost of importing  $F$ , between the chain's profit conditional on purchasing the input from offshore producers (with the conditionally-optimal chain size  $k_1^*$ , selling the conditionally-optimal number of units  $x_1^*$  per store) and the chain's profit conditional on purchasing the input domestically (with the conditionally optimal chain size

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<sup>28</sup>If  $\alpha_1$  is small enough, the contestable-market constraint will never bind for an importing chain.

$k_0^*$ , and selling  $x_0^*$  per store). We suppress the parameter  $\alpha_0$  in the second profit function because we treat it as a constant. Because  $G(\cdot, \cdot)$  is the difference between the conditional optimized profits, net of  $F$ , it depends only on the parameters of the model and not on any decision variables. By construction,  $G > 0$ ;  $G$  is not a function of  $F$  because this fixed cost cancels out a negative term in  $\pi(k_1^*, x_1^*, 1)$ . The optimal input source is  $\theta^* = 1$  if and only if  $G \geq F$ .

### 3.3 Technological Change and Trade Liberalization

We can now analyze the effect of an improvement in the chain's technology (a rise in  $\delta$ ) on imports. We continue to abstract away from the technology-investment decision and treat the technology parameter  $\delta$  as exogenous. Our first result establishes that the decision to purchase input from offshore producers depends on  $\delta$ : the chain only imports its input if its technological advantage is sufficiently large.

**Result 1 (Technological Change).** *If  $F$  is not too high, there exists some  $\delta_m < \infty$  such that:*

1. *The chain purchases the input domestically when  $\delta < \delta_m$ , and imports the input once its chaining technology exceeds this level;*
2. *For  $\delta \geq \delta_m$ , the chain's size, units sold per store, total import volume ( $kx$ ) and import value ( $kxp(x)$ ) all increase with  $\delta$ .*

Result 1, combined with our earlier discussion of the effect of  $\delta$  on chain size in the case of domestic production, implies that if  $\delta$  rises over time the chain eventually starts to import its input. By Lemma 1, it also increases in size discretely at that point.<sup>29</sup> This result holds only if  $F$  is not too large; if the fixed cost  $F$  of importing is too high, the variable-cost savings

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<sup>29</sup>A discrete increase in the optimal chain size  $k^*$  is mitigated by real-world frictions such as "time to build" (Koeva (2000)), so we do not expect to see a sudden sharp increase in the number of Wal-Mart stores.

from importing the input can never justify incurring the cost  $F$ . In that case,  $\delta_m$  would be infinite and the input would be purchased domestically regardless the chain's technology parameter. We assume that  $\delta_m > \delta_c$ : the threshold for importing exceeds the threshold for chaining.

Part 1 of Result 1 is consistent with the experience of Wal-Mart in the late 1980s and early 1990s. Between 1985 and 1995, Wal-Mart's chaining technology improved dramatically with the introduction of "Retail Link," an innovative distribution system connecting its stores, distribution centers, headquarters and suppliers. Wal-Mart more than doubled in size over this period, transitioning from a regional chain with 859 stores in 22 states to a national chain with 1880 stores in 46 states. And, at the same time, Wal-Mart launched, and then retreated from, a massive "Buy American" campaign.

Part 2 of Result 1 is also consistent with the empirical evidence. The simultaneous rise in U.S. Wal-Mart sales and U.S. imports from China was shown in Figure 1. Over the period 1984-2004, Wal-Mart's share of U.S. retail sales increased from 0.1% to 7.4%; imports from China have grown at an even faster rate, and prices of clothes, toys and electronics — items increasingly imported from China and other LDCs — have fallen considerably. Apparel prices, for example, fell by 55% relative to the overall price level between 1980 and 2004, and toy prices fell by 87% relative to the overall price level over this period.

To analyze the effect of a reduction in tariffs on  $k^*$  and  $x^*$ , we explicitly write the base cost of a unit produced offshore as  $\tilde{\alpha}_1 + \tau$ , with  $\tilde{\alpha}_1$  the production cost, and  $\tau$  the import tariff (assume the transport cost is zero).

**Result 2 (Trade Liberalization).** *If  $F$  is not too high, there is some  $\tau_m < \infty$  such that:*

1. *The chain purchases the input domestically when  $\tau > \tau_m$ , and imports the input once the tariff falls below this level;*
2.  *$\tau_m$  is increasing in  $\delta$ ;*

3. For  $\tau \leq \tau_m$ , the chain's size, units sold per store, total import volume and value all increase as  $\tau$  declines.

This result is a consequence of the fixed cost of purchasing the input from offshore producers: this creates a threshold market size for offshore production. As the cost advantage of offshore producers increases (with a decline in trade costs), the threshold market size declines. Improvements in the chain's technology increase its market size, raising the upper bound on trade barriers that can support trade. Once  $\tau$  falls below this upper bound (at which point the chain begins to import, and increases discretely in size), any further trade liberalization increases the chain's size.

For  $\tau \leq \tau_m$ , we decompose the effect of lower trade barriers (a reduction in  $\tau$ ) on total imports ( $k \cdot x$ ) as follows:

$$\frac{d(k^* \cdot x^*)}{d\tau} = k^* \cdot \left( \frac{\partial x^*}{\partial \tau} + \frac{\partial x^*}{\partial k} \frac{dk^*}{d\tau} \right) + x^* \cdot \frac{dk^*}{d\tau}.$$

This decomposition allows us to identify three distinct effects:

1. **Demand effect:**  $k \cdot \frac{\partial x}{\partial \tau}$ . This is the “conventional” effect, which works through the increase in demand in a fixed number of locations due to lower unit cost.
2. **Expansion effect:**  $x \cdot \frac{dk}{d\tau}$ . This effect works through the expansion of the chain. In our simple model, stand-alone retailers do not import at all, while the chain sells imported goods exclusively. More generally, as long as stand-alone retailers have a lower import share than the chain, the expansion of the chain increases imports.
3. **Scale effect:**  $k \cdot \frac{\partial x}{\partial k} \frac{dk}{d\tau}$ . As the chain expands, its unit marketing cost falls, which further lowers its retail price and increases imports.

All three of these effects work in the same direction. Together, they provide an alternative explanation for the “tariff elasticity puzzle” of Yi (2003). Yi argues that the response of trade volumes to tariff reductions over the past two decades implies an implausibly high



price elasticity of demand. Here, the existence and expansion of the chain amplifies the demand effect. Because the expansion and scale effects are of the same order as the demand effect, this amplification can be quite large.

A further amplification of the effect of tariffs on imports can arise through the chaining technology, and in particular, through the interaction between trade liberalization and technological change. This channel provides a complementary mechanism through which a tariff reduction can have not only an amplified effect on imports, but one that increases over time, consistent with the observation that the relationship between tariff reductions and trade has become more pronounced over time.

As implied by Results 1 and 2, if  $\delta$  is very low the chain purchases its input domestically regardless of  $\tau$ . As the chain's technology improves the range of values of  $\tau$  for which the chain chooses to import the input increases, and a small reduction in tariff is increasingly likely to shift the optimal input source from domestic to foreign manufacturers. Thus, the improvements in Wal-Mart's chaining technology and gradual reductions in tariffs may have worked together to bring about the large increase in Chinese imports observed in the 1990s. This technology-dependent tariff threshold can also explain why Wal-Mart is perceived to import not only more than stand-alone retailers, but also more than many smaller chains.

Once  $\tau$  falls below  $\tau_m(\delta)$ , further increases in  $\delta$  interact with the falling level of  $\tau$  to increase imports at an increasing rate. The effect of an increase in  $\delta$  on the relationship between tariffs and imports can be written as:

$$\frac{d^2(k^* \cdot x^*)}{d\delta d\tau} = \frac{dk^*}{d\tau} \frac{dx^*}{d\delta} + \frac{dx^*}{d\tau} \frac{dk^*}{d\delta} + k^* \frac{d^2x^*}{d\delta d\tau} + x^* \frac{d^2k^*}{d\delta d\tau}. \quad (8)$$

The following functional forms meet our assumptions:<sup>30</sup>

$$\begin{aligned} p(x) &= a - bx \\ c(k) &= \frac{(k-1)^2}{2} \\ S(kx) &= skx - \frac{\sigma}{2}(kx)^2, \end{aligned}$$

the first derivatives of  $k^*$  and  $x^*$  with respect to the parameters  $\delta$  and  $\tau$ , when  $\tau \leq \tau_m$ , are

$$\begin{pmatrix} \frac{dx^*}{d\tau} \\ \frac{dk^*}{d\tau} \\ \frac{dx^*}{d\delta} \\ \frac{dk^*}{d\delta} \end{pmatrix} = \frac{1}{(2b - k^*\sigma) \left(\frac{1}{\delta} - (x^*)^2\sigma\right) - k^*(x^*\sigma)^2} \begin{pmatrix} -\frac{1}{\delta} \\ -2bx^* \\ \frac{(k^*-1)x^*\sigma}{\delta^2} \\ \frac{(k^*-1)(2b-k^*\sigma)}{\delta^2} \end{pmatrix}.$$

where  $(2b - k^*\sigma) > 0$  and  $(2b - k^*\sigma) \left(\frac{1}{\delta} - (x^*)^2\sigma\right) - k^*(x^*\sigma)^2 > 0$  by the second-order conditions for a maximum (see Appendix A). This establishes that the first two terms in Equation (8) are negative. We show in Appendix A that the cross-partial terms are also negative, so that the term  $\frac{d^2(k^* \cdot x^*)}{d\delta d\tau}$  is unambiguously negative: the sensitivity of imports to tariff reductions increases as the chaining technology improves. This also implies that the effect of a technological improvement on chain size and units sold per store is larger when the chain imports the input (i.e., when  $\alpha = \alpha_1$ ) than when it purchases it domestically ( $\alpha = \alpha_0$ ). A combination of a decline in trade costs and an improvement in Wal-Mart's (and others') chaining technology could act together to increase both trade and chain size — with both changes affecting both outcomes. Indeed, the effect of trade liberalization on imports was small as long as the U.S. retail sector was relatively fragmented — in 1972, for example, only 15% of retail stores belonged to chains, and only 6% to large chains (see Table 2). By 1992, when 33% of retail stores belonged to chains, and 17% to large chains — the available

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<sup>30</sup>To ensure that  $S(\cdot)$  is everywhere increasing, we assume that  $s > \frac{\sigma Na}{b}$ . We also assume that  $s > h$  and  $\frac{2(s-h)}{\sigma} > \frac{a}{b}$  to ensure that  $z > \bar{x}$ .

“chaining technology” having improved considerably over this period, with the introduction of bar codes and better computer systems — imports from China and elsewhere increased dramatically in response to small tariff reductions.

Finally, we note that while our discussion focused on the effect of a reduction in tariffs, the analysis applies equally to other cost reductions. An increasing share of international trade has shifted from ocean shipping, whose costs have been roughly constant since the 1950s, towards air transport, whose costs have declined sharply since the 1970s (Hummels (1999)). Combined, these trends imply a decline in average shipping costs, which will have the same effect as a decline in tariffs in our model. The analysis also applies to reductions in production costs. A decrease in the production cost  $\tilde{\alpha}_1$ , for example due to learning-by-doing or cost-reducing investment in human capital, induces chain expansion and thus amplifies the effect on imports. A decrease in the value of the foreign currency (say, the yuan) which would effectively reduce the dollar value of  $\tilde{\alpha}_1$ , would have the same effect. Many have argued in recent years that the yuan is undervalued. A revaluation of the yuan would, in our model, amount to an *increase* in  $\alpha_1$  and would slow imports from China — by increasing their price, and also by reducing the optimal rate of Wal-Mart’s expansion.

## 4 Induced Technical Change

So far, we have treated  $\delta$  as an exogenous parameter. In reality, however, a retailer has a choice of technology level. Wal-Mart chose to invest in computers in its early years, in the “Retail Link” software in the 1980s and 1990s, and more recently in RFID technology. Other chains, notably Target and Walgreen’s, have made similarly large investments in their respective chaining technologies, especially in the past decade. We show below that endogenizing the retailer’s technology level further amplifies the effect of lower trade barriers on imports.

To capture the retailer’s technology choice, we introduce a new function,  $I(\delta)$ , with

$I(0) = 0$ ,  $I' > 0$ ,  $I'' > 0$ . That is, where we have previously used  $\delta$  as a primitive reflecting the chain's advantage over other retailers, now the function  $I(\cdot)$  is the primitive: only the chain has access to this investment function, and it can use it to achieve any level of chaining technology  $\delta \geq 0$ . To conserve on notation, we use the convention that if  $k = 1$  and  $\delta = 0$ ,  $\frac{c'(k)}{\delta} = 0$ .

The chain's maximization problem becomes

$$\begin{aligned} \max_{k,x,\theta,\delta} \quad & \pi(k, x, \delta, \theta) = kx(p(x) - (1 - \theta)\alpha_0 - \theta\alpha_1) \\ & - \min\{hkkx, S(kx)\} - \frac{c(k)}{\delta} - \theta F - I(\delta) \\ \text{subject to} \quad & k \in [1, N] \\ & x \geq 0 \\ & \theta \in \{0, 1\} \\ & \delta \geq 0. \end{aligned}$$

The new first-order condition, with respect to  $\delta$ , is

$$\delta^2 I'(\delta) = c(k), \tag{9}$$

with the other first-order conditions unaffected. The solution is shown graphically in the  $(k, \delta)$  plane in Figure 8. The thick-set solid line  $k^*(\delta; \tau_1)$  is the solution, for a given  $\tau_1$ , to the simultaneous equation problem  $(x^*(k), k^*(x))$ , taking  $\delta$  as given. We showed earlier that  $k^*(\delta) = 1$  for  $\delta < \delta_c$ : if it is sufficiently costly for the chain to expand, it prefers to emulate a stand-alone retailer. The optimal chain size increases discretely at  $\delta_c$  and again at  $\delta_m$ , when the chain begins importing the input; for all other values of  $\delta > \delta_c$ ,  $k^*(\delta)$  increases smoothly with  $\delta$ . The thin curve  $\delta^*(k)$  is the solution to Equation (9); it does not depend on either  $\theta$  (the import decision) or  $\tau$  directly.

For all parameter values, there is a local maximum at  $(k^*, \delta^*) = (1, 0)$ , at which the

chain emulates a stand-alone store, and does not invest in chaining technology. Sufficient conditions for an interior solution to exist as well are

(i)  $\delta^*(k^*(\delta_c)) > \delta_c$ ,<sup>31</sup>

(ii)  $\frac{d\delta^*}{dk} < \frac{1}{dk^*/d\delta}$ .

Using the function  $I(\delta) = i \cdot \delta^2$ , where  $i > 0$  is a constant, these conditions place upper and lower bounds, respectively, on the parameter  $i$ . Given the two local maxima, the chain compares profits at the corner and interior solutions to determine which maximum is global. Since  $\pi = 0$  for the corner solution, the interior solution is a global maximum if and only if it yields a positive profit; for  $\tau$  low enough, the interior solution dominates.

The dotted line  $k^*(\delta; \tau_2)$  in Figure 8 shows how  $k^*(\delta)$  responds to a reduction in tariff. Both  $\delta_c$  and  $\delta_m$ , the technology thresholds for chaining and imports, respectively, fall; and  $k^*(\delta; \tau)$  increases for all values of  $\delta \geq \delta_m$ . As in the earlier analysis with exogenous  $\delta$ , a decline in  $\tau$  increases chain size. What is new here is that the effect on  $k^*$  can be decomposed into two parts: holding  $\delta$  fixed, there is an increase in  $k^*(\delta)$ , as explained above. In addition, because  $\delta^*$  is an increasing function of  $k$ , a decline in tariffs leads to higher investment in chaining technology, which also increases  $k^*$ .

Endogenizing the chain's technology level therefore adds a fourth component to the effect of lower trade barriers (a reduction in  $\tau$ ) on total imports:

4. **Investment effect:**  $x \cdot \frac{\partial k}{\partial \delta} \frac{d\delta}{d\tau}$ . Lower trade barriers increase the benefit of chaining by increasing profit per store for a fixed value of  $\delta$ ; but because the benefit of investing in chaining increases with the size of the chain,  $\delta$  also increases, raising further the size of the chain.

There is a parallel between the investment effect and the result of “directed technical change” in recent models of endogenous technological change (see Acemoglu (2002a)). Im-

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<sup>31</sup>Technically,  $k^*(\delta_c)$  is set-valued,  $k^*(\delta_c) = \{1, k(\delta; \tau)\}$ ; we save on notation by assuming that when  $\delta = \delta_c$  the retailer will set  $k^*(\delta_c) > 1$ .

ports are an input of the chain retailer; as this input becomes cheaper the chain has an incentive to invest in technology that takes advantage of the cheaper input. In our context the technology takes the form of improvements in the organization and logistics of the chain, which complements the increasingly-abundant cheap imports.

## 5 Product Cycle

In this section we generalize our model by adding many potential production locations in order to analyze the relationship among trade policy, chain size and the product cycle. We show that the product cycle — the migration of production from one country to the next — is accelerated by the existence of the chain, and adds another layer to the effect of a tariff reduction on import volume.<sup>32</sup>

Assume an infinite number of possible production locations parameterized by the pair  $(\alpha, F) \in \Phi$  where  $\Phi$  is a compact subset of  $\mathfrak{R}_{++} \times \mathfrak{R}_+$ . As before,  $\alpha$  is the marginal cost of production (inclusive of tariff) and  $F$  is the retailer’s fixed cost of importing from the country; the domestic location is the only one where  $F = 0$ .<sup>33</sup>

The retail chain chooses the production location to maximize profit. We write the optimization problem as follows:

$$\max_{(\alpha, F) \in \Phi} G(\alpha, \delta) - F$$

where  $G(\cdot, \cdot)$  is defined in Equation (7), and the discrete variable  $\theta$  is replaced by a continuous choice represented by  $(\alpha, F) \in \Phi$ . Define  $\tilde{F}(\alpha)$  as the lowest value  $F$  for given value of  $\alpha$ . The solution to the retailer’s optimization problem is restricted to the set of points

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<sup>32</sup>The product cycle usually refers to the process starting from a good’s introduction in an industrialized country to the migration of its production, first to other industrialized countries and eventually to developing countries. Our context is one where the good is mature and so the product cycle here refers to the migration of production from one developing country to another.

<sup>33</sup>Alternatively, the domestic location may have two production options, one of which is domestic contract manufacturing with some small fixed cost.

$\{(\alpha, \tilde{F}(\alpha))\} \subset \Phi$ . Since  $F = 0$  only for the domestic location, the solution is further restricted to locations with  $\alpha \leq \alpha_0$ . To simplify the exposition, assume that  $\Phi$  is strictly convex. This implies that  $\tilde{F}(\alpha)$  is downward-sloping and convex in  $\alpha$ . The function  $\tilde{F}(\alpha)$  is shown as the dotted curve in Figure 9.

We can also represent  $G(\alpha; \delta)$  in Figure 9. By definition,  $G(\alpha_0, \delta) \equiv 0$  for all values of  $\delta$ . By the envelope theorem,  $\frac{\partial G}{\partial \alpha} < 0$  and  $\frac{\partial G}{\partial \delta} > 0$  for interior solutions when  $\alpha > \alpha_0$ , so  $G(\alpha, \delta)$  is downward-sloping and becomes steeper, rotating clockwise about the point  $(\alpha_0, 0)$ , as  $\delta$  increases.

In Figure 9 we show the curves  $G(\alpha, \delta)$  for three different values of  $\delta$ , with  $\delta_1 < \delta_2 < \delta_3$ . The optimum for each value of  $\delta$  (which is again treated as exogenous) is the point on the  $\tilde{F}(\alpha)$  curve that maximizes the vertical gap between the curves  $G(\alpha, \delta_1)$  and  $\tilde{F}(\alpha)$ . For low values of  $\delta$ , such as  $\delta = \delta_1$ , the optimum is point A: domestic production. When  $\delta$  reaches a sufficiently high level, production moves to a foreign location; at  $\delta = \delta_2$ , the retailer purchases input from the location denoted by point B. As the chaining technology improves further ( $\delta = \delta_3$ ), production moves to another location denoted by point C. As a possible example of this sort of shift, India is currently Wal-Mart's largest-growing supplier, with exports of \$1.5 billion through Wal-Mart (Augustine, Sieber, and Uy (2005)). Gereffi (1999) counts three or four major shifts of offshore apparel production since the 1950s: to Japan; to the "Big Three" Asian producers (Hong Kong, Taiwan, South Korea); and from the Big Three to China and a few other Southeast Asian countries (including Sri Lanka), with several more countries, including Vietnam, expected to emerge as large producers in the near future.<sup>34</sup>

We can also use Figure 9 to analyze the effect of a uniform tariff reduction. Suppose that all locations (except the domestic location) have the same tariff  $\tau$ , and redefine the horizontal axis of Figure 9 to be  $\tilde{\alpha} = \alpha - \tau$ . The effect of a decrease in  $\tau$  in this setting is similar to an increase in the chain's efficiency  $\delta$ . If the chain initially purchased the input

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<sup>34</sup>There is also evidence that differently-sized U.S. retailers import from different countries and regions; see Gereffi (1994).

from domestic producers (i.e., starting from point A), a uniform reduction in tariff would have the standard effect of moving production abroad; but if initial production were in a foreign location, such as B, a uniform tariff reduction would move the chain’s optimal source to a different country, such as C. A uniform reduction in tariffs can therefore hurt some trading partners while helping others. This result could explain the empirical observation that China’s share of U.S. imports has increased — and Latin America’s has fallen — despite broadly similar tariff treatment in the 1980s and 1990s (see, e.g., Moreira (2004)). A high uniform tariff that applies to all non-domestic producers therefore protects not only domestic manufacturers, but also incumbents that are “close” to the domestic market on the  $\tilde{F}(\alpha)$  locus.<sup>35</sup>

Endogenizing the chain’s technology parameter  $\delta$  in the presence of many potential production locations adds yet another effect of a tariff reduction on import volume. As in the previous section, a reduction in the tariff  $\tau$  increases the chain’s optimal choice of  $\delta$ . This, in turn, rotates the curve  $G(\alpha, \delta)$  clockwise, moving the optimal source of input to a “further” country — in other words, lowering the unit production cost  $\tilde{\alpha}$ , which increases both the size of the chain and its sales per store:

5. **Product-cycle effect:**  $\frac{\partial(kx)}{\partial\alpha} \frac{d\alpha}{d\delta} \frac{d\delta}{d\tau}$ . A uniform reduction in tariff for all trading partners increases the chain’s investment in chaining technology, which, by increasing market size, moves the optimal input source to a country with lower unit costs, further increasing profit per store and inducing further increases in the size of the chain and sales per store.

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<sup>35</sup>The movement of industries across countries may be partially mitigated by the importance of physical distance. Moreira (2004) reports that from 1990-2002, over four per cent of world market share in manufacturing were lost to China in Brazil, in the Mercosur countries, and the Andean countries compared to Mexico’s loss of 0.3%. Manufacturing in the East Asian countries lost 8.1% to China. Evans and Harrigan (2005) argue that for goods where timeliness matters, physical distance is paramount. They find that, from 1990-98, imports of “more-often-replenished” apparel goods to the U.S. grew more quickly for proximate countries like Mexico than far-away countries like China, implying that for some industries, the importance of physical distance may dominate the effect discussed in this section.



## 6 Concluding Remarks

Our goal in this paper has been to uncover the link between recent trends in the U.S. retail sector and trends in the location of manufacturing jobs and the volume of imports. We rely on the interaction between scale economies in the retail sector and scale economies in the import process to generate a two-way relationship between import volume and chain size, and show that this interaction has implications for trade volume and the sensitivity of imports to tariff reductions. Technological innovations in the retail sector increase chain size and, by increasing market size, also increase imports. Likewise, reductions in the cost of merchandise (due, for example, to tariff reductions or currency devaluation) increase both imports and the size of the dominant retailer. When the retailer's level of investment in the chaining technology is endogenized, we obtain a result akin to "directed technical change" in that the retailer's investment in chaining technology increases as imports become cheaper and more abundant.

Many observers (e.g., McKinsey Global Institute (2001)) have noted the retail sector's high productivity growth rate in the 1990s relative to the rest of the economy. Wal-Mart has been cited as an important source of the productivity increase. Wal-Mart's transition to cheaper inputs provides an alternative explanation for its high observed productivity; as a matter of accounting, cheaper inputs may be indistinguishable from superior technology in productivity calculations. Our contribution in this paper is to highlight the interaction between these two explanations. Wal-Mart, as the canonical example of a large retail chain, serves as a conduit for imports and its technological advantage is a necessary ingredient for enlarging the market for these imports.

While our discussion has centered on the effect of a decline in tariffs on chain size and import volume, the feedback effect the chain exerts on imports is also present when foreign production costs fall. Any decline in the cost of production in China, for example due to investment in human or physical capital, relaxation of regulation, or learning, increases the optimal size of the retail chain, and so increases imports not only through the direct demand

effect, but also by expanding the chain and its level of investment in “chaining” technology.

Our model abstracts from competition between chains to highlight the effect of increasing returns when there is a single chain competing against stand-alone “fringe” firms. If there are multiple firms with access to chaining technology, and their unconstrained sizes sum to more than the number of available retail locations, interesting strategic considerations arise. First, the price constraint faced by a chain store may be determined not by potential entry of a stand-alone retailer but by potential expansion of an existing competing chain. In addition, from a modeling perspective, timing starts to matter. In the one-chain model, the retailer’s choices — chain size, units sold per store (alternatively, retail price), the location of production, and possibly the level of investment in technology — are treated as simultaneous; the true timing of these decisions does not matter since there is no strategic element in the retailer’s decision-making. With multiple chains, however, simultaneous and sequential choices will yield very different outcomes. Extending the model to address these issues may yield further insights into the equilibrium distribution of chain size and the relationship between the size of chains and import volumes.

The implications of our model extend to a situation with many goods or industries. Suppose that the chain retailer sells many goods, which vary with respect to the gap in unit production costs between domestic and foreign manufacturers. This variable gap may reflect different degrees of “maturity” of the goods or the extent to which foreign producers have “caught up” with domestic producers. When the chain is small, only industries with a sufficiently large gap in unit production costs are located offshore, with the remaining industries producing domestically. As the chain expands — e.g., in response to trade liberalization — more and more industries move offshore. The pace of this offshoring of production is directly related to the response of chain size to trade liberalization, which, as before, is greater the better the chain’s technology.

The trend towards foreign outsourcing of production has been mentioned with regularity recently in the popular press, as have reports of Wal-Mart’s low wages. An extension of our

model suggests a mechanism through which these two issues are related. In a general-equilibrium framework with skilled and unskilled workers, increased trade with China and other developing countries reduces the relative wage of unskilled workers. If the chain retailer employs unskilled service workers, this wage decline operates as a cost reduction and creates an incentive to expand the chain. Chain expansion leads to more imports and offshoring of production, depressing the unskilled wage further. Improvements in chaining technology therefore reduce the bargaining power of unskilled labor, amplifying the effect of technological change on the size of the chain. Note that this is a different mechanism than the usual theories of skilled-biased technological change (see, e.g. Acemoglu (2002b), Autor, Katz, and Krueger (1998)); in our model, technological change affects the labor market but it is by way of trade.

Our analysis focuses on the retailer's choice of the location of private-label production facilities, since half of Wal-Mart's imports are made directly through contract manufacturers offshore. The other half, however, is produced offshore not because of any explicit decision by Wal-Mart, but because large-scale suppliers from the U.S. and Europe have found it profitable to move their production facilities offshore. Our results would likely carry over to that setting. If the cost of linking to a foreign contract manufacturer is borne not by the retailer but by the supplier (such as General Electric or Proctor and Gamble), market size should again play an important role in the decision. But there is one key difference. In this case the fixed cost of importing implies an imperfectly-competitive manufacturing sector. The details of the results may depend on how this competition is modeled. One interesting implication of such a set-up that is different from our model is that once the decision is made to move production offshore, the supplier sells its lower-cost product to *all* retailers, including stand-alone stores. This implies that the expansion of the chain, by increasing aggregate market size through lower prices, creates an externality for smaller stores. Consumers in markets not served by the chain could therefore still benefit from the chain's expansion.

In conclusion, we note that our model highlights a mechanism not usually mentioned

in popular discourse. There is a common perception that Wal-Mart and trade with China are related. But the discussion of the relationship between Wal-Mart's growth and import growth tends to focus on Wal-Mart's monopsony power implied in the often-made claim that Wal-Mart "forces" suppliers to move production overseas in order to cut costs. In a model with increasing marginal cost, a monopsonist who cannot perfectly price-discriminate depresses production to extract a lower input price. Such a model counter-intuitively implies that in the absence of Wal-Mart and other large chains, imports would have grown at a rate even faster than the one we have observed over the past two decades. While we do not deny the importance of issues arising from Wal-Mart's market power beyond its role as seller, discussions of such issues are taking place without the benefit of formal analysis. Our model is a starting point from which to bring economic analysis into this important debate surrounding Wal-Mart's role in an increasingly-globalized setting.

# A Proofs

*Existence of Equilibrium.* The chain retailer solves the following problem

$$\begin{aligned} \max_{k,x} \quad & \pi(k, x) = kx(p(x) - \alpha) - \min\{hkkx, S(kx)\} - \frac{c(k)}{\delta} \\ \text{subject to} \quad & k \in [1, N] \\ & x \geq 0 \end{aligned}$$

where  $p = \alpha + h$  for  $x \leq x_s$  and  $p(x)$  is the unconstrained price given by the market inverse demand function for  $x > x_s$ .

As noted in the text (Section 3.1), a local maximum  $(k, x) = (1, x_s)$  exists and guarantees zero profit using the linear marketing technology, for all  $\delta > 0$ . If a solution  $(k^*, x^*)$  exists such that  $k^* \cdot x^* > z$  it must satisfy the first-order conditions

$$x \cdot (p(x) - \alpha - S'(kx)) - \frac{c'(k)}{\delta} = 0 \tag{10}$$

$$k \cdot (p'(x)x + p(x) - \alpha - S'(kx)) = 0, \tag{11}$$

along with second-order conditions. If a solution to Equations (10) and (11) with  $kx > z$  — when the chain is large enough to profitably use the convex marketing technology — exists and yields a positive profit, this solution is the retailer's optimum. Alternatively,  $(1, x_s)$  is the global optimum whenever a solution to Equations (10) and (11) does not exist or when a solution exists but yields negative profit. Which solution dominates depends on the value of  $\delta$ .

Consider the case when the retailer uses the convex marketing technology and the price constraint does not bind. In this case,  $p(x)$  is downward-sloping ( $p'(x) < 0$ ). Let  $k^*(x)$  be the solution to the first-order condition with respect to  $k$ , Equation (10), and let  $x^*(k)$  be the solution to the first-order condition with respect to  $x$ , Equation (11). A local maximum,  $(k^*, x^*)$ , simultaneously solves the Equation (10) and (11), along with second-order conditions

defined below. Graphically, this is the intersection of  $x^*(k)$  and  $k^*(x)$  in the  $(k, x)$  plane (see Figures 5 and 6).

The second-order conditions are derived from the condition that the Hessian matrix is negative semi-definite:

$$\pi_{kk} = - \left( x^2 S''(kx) + \frac{c''(k)}{\delta} \right) < 0 \quad (12)$$

$$\pi_{xx} = k(p''(x)x + 2p'(x) - kS''(kx)) < 0 \quad (13)$$

$$\begin{aligned} \pi_{xx}\pi_{kk} - \pi_{kx}^2 &= -k(p''(x)x + 2p'(x) - kS''(kx)) \left( x^2 S''(kx) + \frac{c''(k)}{\delta} \right) \\ &\quad - \left( p'(x)x + p(x) - \alpha - S'(kx) - kxS''(kx) \right)^2 > 0. \end{aligned} \quad (14)$$

One way to interpret these conditions is as a set of restrictions on the magnitude of  $S''(\cdot)$ , or the degree of increasing-returns in the chain's marketing technology. The marketing component of marginal cost,  $S'(kx)$ , falls when either  $k$  or  $x$  increases; an interior optimum can only exist if it does not fall too rapidly. Equation (13) bounds the extent of increasing returns due to increasing  $x$  relative to the decline in marginal revenue from increasing  $x$ , holding  $k$  constant. Equation (12) bounds the extent of increasing returns due to increasing  $k$  (now holding  $x$  constant) relative to the increased chaining cost entailed in increasing  $k$ . Equation (14) bounds the extent of increasing returns when  $x$  and  $k$  are allowed to co-vary. Since  $x$  and  $k$  move together (see below), for some functional-form assumptions this condition is sufficient and implies the previous two.

An interior intersection of  $k^*(x)$  and  $x^*(k)$  occurs if:

1.  $x^*(0) > k^{*-1}(0)$ , that is, if the  $x$ -intercept of  $x^*(k)$  is above the  $x$ -intercept of  $k^*(x)$ ;
2.  $\frac{dx^*(k)}{dk} > 0$ ,  $\frac{dk^*(x)}{dx} > 0$  over all the relevant range; and
3.  $\frac{1}{\frac{dk^*(x)}{dx}} > \frac{dx^*(k)}{dk}$ .

To see that the first condition is satisfied, from Equation (6), check that for  $k = 0$ ,  $x^* > 0$ ; and from Equation (10), for  $x = 0$ ,  $k^* = 0$ . For the second condition, differentiate the two

first-order conditions to get:

$$\frac{dk^*(x)}{dx} = \frac{-\pi_{kk}}{\pi_x/k - kxS''(kx)} \quad (15)$$

$$\frac{dx^*(k)}{dk} = \frac{xS''(kx)}{\pi_{xx}/k}. \quad (16)$$

The numerator of Equation (15) is positive by second-order condition (12). For  $x < x^*(k)$ ,  $\pi_x > 0$  so the denominator is also positive and  $\frac{dk^*(x)}{dx} > 0$ . For  $x > x^*(k)$ ,  $\pi_x < 0$ , but in the neighborhood of  $x^*$   $\pi_x$  is not too negative, so the denominator remains positive. As  $x$  increases beyond some level,  $\pi_x$  becomes sufficiently negative that  $\frac{dk^*(x)}{dx}$  turns negative. By the second-order condition (13) and concavity of  $S(\cdot)$ , both the numerator and the denominator of Equation (16) are negative, so  $\frac{dx^*(k)}{dk} > 0$ .

The third condition,  $\frac{1}{dk^*(x)/dx} > \frac{dx^*(k)}{dk}$ , can be written explicitly as

$$\frac{\pi_x/k - kxS''(kx)}{-\pi_{kk}} > \frac{xS''(kx)}{\pi_{xx}/k},$$

and, after some algebraic manipulation, as

$$\pi_{xx}\pi_{kk} - \left(\frac{\pi_x}{k} - kxS''(kx)\right)^2 > \left(kxS''(kx) - \frac{\pi_x}{k}\right)\frac{\pi_x}{k}.$$

The term on the left-hand side is positive by second-order condition (14). The right-hand side is negative for  $x < x^*(k)$ , equals zero at  $x = x^*(k)$  and turns positive for  $x > x^*(k)$ . As above, in the neighborhood of  $x^*$  the RHS term is not too positive, and the inequality holds.

The above shows that an interior solution exists to the retailer's optimization problem when the price it charges is not constrained by potential entrants and it uses the convex marketing technology. If a solution to the unconstrained problem exists but yields negative profit, then the retailer will prefer to set  $x^* = x_s$  and  $k^* = 1$ . This occurs, for instance, when  $\delta$  is very low.

The final possibility is that the price constraint binds so that  $x^* = x_s$  but that  $k^*x^* > z$

so that the increasing returns technology is used. In this case,  $k^* \in \left[ \frac{z}{x_s}, \bar{k} \right]$  (where  $\bar{k}$  is the chain size beyond which the price constraint no longer binds), solves:

$$x_s \cdot (h - S'(k^* x_s)) - \frac{c'(k^*)}{\delta} = 0.$$

A solution to the above is guaranteed to exist for some range of  $\delta$  if  $h - S'(x_s) > 0$  and  $-x_s^2 S''(k^* x_s) < \frac{c''(k^*)}{\delta}$  for  $k^* \in \left[ \frac{z}{x_s}, \bar{k} \right]$ .  $\square$

*Comparative Statics with Domestic Production.* First, we show that for  $\delta \geq \delta_c$ ,  $\frac{dk^*}{d\delta} > 0$  and  $\frac{dx^*}{d\delta} > 0$ . Note that for  $\delta \geq \delta_c$ ,  $k^* \geq \bar{k}$  so the chain is operating in the region where  $k^* x^* > z$ , i.e., it is using the convex marketing technology. For the case of domestic production, the optimum  $(x^*, k^*)$  satisfies the first-order conditions:

$$\begin{aligned} \pi_x &= k(p'(x)x + p(x) - \alpha - S'(kx)) = 0 \\ \pi_k &= p(x)x - \alpha x - S'(kx)x - \frac{c'(k)}{\delta} = 0. \end{aligned}$$

Differentiating with respect to  $\delta$ , we obtain the following system of equations:

$$\begin{pmatrix} \pi_{xx} & \pi_{xk} \\ \pi_{kx} & \pi_{kk} \end{pmatrix} \begin{pmatrix} \frac{dx^*}{d\delta} \\ \frac{dk^*}{d\delta} \end{pmatrix} = \begin{pmatrix} -\frac{\partial \pi_x}{\partial \delta} \\ -\frac{\partial \pi_k}{\partial \delta} \end{pmatrix} = \begin{pmatrix} 0 \\ -\frac{c'(k)}{\delta^2} \end{pmatrix}$$

which we solve using Cramer's Rule to obtain:

$$\begin{pmatrix} \frac{dx^*}{d\delta} \\ \frac{dk^*}{d\delta} \end{pmatrix} = \frac{1}{|\mathbf{H}|} \begin{pmatrix} \frac{c'(k)}{\delta} \pi_{xk} \\ -\frac{c'(k)}{\delta} \pi_{xx} \end{pmatrix} = \frac{1}{|\mathbf{H}|} \begin{pmatrix} -\frac{c'(k)}{\delta^2} kx S''(kx) \\ -\frac{c'(k)}{\delta^2} k(p''(x)x + 2p'(x) - kS''(kx)) \end{pmatrix},$$



where  $|\mathbf{H}|$  is the determinant of the Hessian matrix,

$$\begin{aligned} |\mathbf{H}| &\equiv \pi_{xx}\pi_{kk} - \pi_{xk}^2 \\ &= -k(p''(x)x + 2p'(x) - kS''(kx)) \left( x^2 S''(kx) + \frac{c''(k)}{\delta} \right) \\ &\quad - \left( p'(x)x + p(x) - \alpha - S'(kx) - kxS''(kx) \right)^2, \end{aligned}$$

and, at the optimum,  $p'(x)x + p(x) - \alpha - S'(kx) = 0$ .

By the second-order condition,  $|\mathbf{H}| > 0$ . Thus,  $\frac{dk^*}{d\delta} > 0$  and  $\frac{dx^*}{d\delta} > 0$ .  $\square$

*Proof of Lemma 1.* Define  $\Gamma_\theta(k)$  to be the marginal benefit of expanding the chain conditional on an input source  $\theta \in \{0, 1\}$  and choosing the optimal number of units to sell in each of the chain's locations,  $x_\theta^*(k)$ :

$$\begin{aligned} \Gamma_\theta(k) &\equiv \frac{d}{dk} \left( \pi(k, x_\theta^*(k), \theta) + \frac{c'(k)}{\delta} \right) \\ &= \begin{cases} x_\theta^*(k)(p(x_\theta^*(k)) - (1 - \theta)\alpha_0 - \theta\alpha_1 - h) & \text{if } kx \leq z \\ x_\theta^*(k)(p(x_\theta^*(k)) - (1 - \theta)\alpha_0 - \theta\alpha_1 - S'(k \cdot x_\theta^*(k))) & \text{otherwise.} \end{cases} \end{aligned} \quad (17)$$

An interior solution  $k_\theta^*$  — denoting the optimal chain size conditional on the input source — equates  $\Gamma_\theta(k)$  with the marginal cost of expanding the chain,  $\frac{c'(k)}{\delta}$ . Since the marginal cost of chain expansion is increasing in  $k$ , for interior solutions it is sufficient to show that  $\Gamma_1(k) > \Gamma_0(k)$ .

If  $kx < z$ , the chain uses the linear marketing technology, so  $x^*(k) = x_s$  and  $p(x) = \alpha_0 + h$ ; this implies that  $\Gamma_0(k) = 0$  but  $\Gamma_1(k) = (\alpha_0 - \alpha_1)x_s > 0$ .

If  $kx > z$  but  $k < \bar{k}$ , then  $x^*(k) = x_s$  and  $p(x) = \alpha_0 + h$  still, so  $\Gamma_0(k) = (h - S'(kx_s))x_s$  while  $\Gamma_1(k) = (\alpha_0 - \alpha_1 + h - S'(kx_s))x_s > \Gamma_0(k)$ .

If  $kx > z$  and  $k \geq \bar{k}$ , then the contestable-market constraint does not bind, so  $x$  and  $p$  are unconstrained. By the envelope theorem,  $\frac{d\pi}{d\alpha} = \frac{d\Gamma}{d\alpha} = -x_\theta^*(k)$ . Since the first-order condition

(6) implies that  $x_1^*(k) > x_0^*(k)$  in the unconstrained optimization problem,  $\Gamma_1(k) > \Gamma_0(k)$ , and  $k_1^* > k_0^*$  for all interior  $k_0^*$ .

Finally, since  $k_1^* > 1$  for all  $x > 0$ , but  $k_0^* = 1$  for  $x \leq x_s$ , and since  $x^*(k) > 0$  regardless of  $\theta$ , whenever  $k_0^* = 1$  then  $k_1^* > 1$ . Also, since  $N$  is the upper bound for chain size, whenever  $k_0^* = N$  then  $k_1^* = N$ .  $\square$

*Proof of Result 1.1.* To conserve on notation, we write  $G(\delta)$  taking  $\alpha_1$  as a constant. We need to show that there is some value  $\delta_m < \infty$  such that  $F > G(\delta)$  for  $\delta < \delta_m$  and  $F < G(\delta)$  for  $\delta > \delta_m$ .

First, note that for values of  $\delta < \delta_c$ ,  $G(\delta) = (\alpha_0 - \alpha_1)x_s$ . Our assumption that  $\bar{x} < \frac{F}{\alpha_0 - \alpha_1}$  guarantees that  $0 < G(\delta) < F$  for  $\delta < \delta_c$ .

Second, note that for values of  $\delta$  such that  $k_1^*(\delta) < N$ ,  $\frac{dG}{d\delta} = \frac{c(k_1^*) - c(k_0^*)}{\delta^2} > 0$  (by the envelope theorem and Lemma 1), so the benefit of importing increases with the firm's technology parameter (for interior values of  $k$ ). Also, for values of  $\delta$  such that  $k_1^*(\delta) = N$  but  $k_0^*(\delta) < N$ , by the envelope theorem  $\frac{dG}{d\delta} = \frac{c(N)}{\delta^2} + \frac{c'(k_0^*)}{\delta} \frac{dk_0^*}{d\delta}$ , which is also positive (since we have already shown that  $\frac{dk_0^*}{d\delta} > 0$ ). For values of  $\delta$  such that  $k_0^*(\delta) = k_1^*(\delta) = N$ ,  $\frac{dG}{d\delta} = 0$ . Define

$$\delta_N \equiv \min\{\delta : k_0^*(\delta) = N\}.$$

Since  $\delta_m$  is defined by  $G(\delta_m) = F$ , such a threshold exists if  $F < G(\delta_N)$ .  $\square$

*Proof of Results 2.1 and 2.2.* We need to show that there is some value  $\tau_m < \infty$  such that  $F > G(\tilde{\alpha}_1 + \tau, \delta)$  for  $\tau > \tau_m$  and  $F < G(\tilde{\alpha}_1 + \tau, \delta)$  for  $\tau < \tau_m$ .

By construction,  $G(\tilde{\alpha}_1 + \tau, \delta)$  is positive whenever  $\tau < \alpha_0 - \tilde{\alpha}_1$ , which holds by assumption; and  $\lim_{\tau \rightarrow (\alpha_0 - \tilde{\alpha}_1)} G(\tilde{\alpha}_1 + \tau, \delta) = 0$ . By the envelope theorem,

$$\frac{\partial G(\tilde{\alpha}_1 + \tau, \delta)}{\partial \tau} = \frac{\partial \pi^*(k_1^*, x_1^*, 1; \alpha_1, \delta)}{\partial \alpha_1} < 0,$$

so as  $\tau$  decreases,  $G$  gets larger, reaching a maximum (for a given  $\delta$ ) at  $\tau = 0$ .

Define  $\tau_m$  by  $G(\tilde{\alpha}_1 + \tau_m, \delta) \equiv F$ . For  $F < G(\tilde{\alpha}_1 + 0, \delta)$ , there exists  $\tau_m \in (0, \alpha_0 - \tilde{\alpha}_1)$  such that  $G(\delta, \tilde{\alpha}_1 + \tau) < F$  if and only if  $\tau > \tau_m$ .

Differentiating  $G(\tilde{\alpha}_1 + \tau_m, \delta) \equiv F$  implicitly with respect to  $\delta$  and rearranging yields

$$\frac{d\tau_m}{d\delta} = -\frac{\partial G/\partial\delta}{\partial G/\partial\tau}.$$

Since the numerator is positive (see Result 1.1) and the denominator is negative,  $\frac{d\tau_m}{d\delta} > 0$ .  $\square$

*Proof of Results 1.2 and 2.3.* When production has moved offshore, we replace  $\alpha$  with  $\tilde{\alpha}_1 + \tau$ , and write the first order conditions as:

$$\begin{aligned}\pi_x &= k(p'(x)x + p(x) - (\tilde{\alpha}_1 + \tau) - S'(kx)) = 0 \\ \pi_k &= p(x)x - (\tilde{\alpha}_1 + \tau)x - S'(kx)x - \frac{c'(k)}{\delta} = 0.\end{aligned}$$

Differentiating with respect to  $\delta$  and  $\tau$ , we obtain the following system of equations:

$$\begin{pmatrix} \pi_{xx} & \pi_{xk} \\ \pi_{kx} & \pi_{kk} \end{pmatrix} \begin{pmatrix} \frac{dx^*}{d\tau} & \frac{dx^*}{d\delta} \\ \frac{dk^*}{d\tau} & \frac{dk^*}{d\delta} \end{pmatrix} = \begin{pmatrix} -\frac{\partial\pi_x}{\partial\tau} & -\frac{\partial\pi_x}{\partial\delta} \\ -\frac{\partial\pi_k}{\partial\tau} & -\frac{\partial\pi_k}{\partial\delta} \end{pmatrix} = \begin{pmatrix} k & 0 \\ x & -\frac{c'(k)}{\delta^2} \end{pmatrix}$$

which, by Cramer's Rule, gives

$$\begin{pmatrix} \frac{dx^*}{d\tau} \\ \frac{dk^*}{d\tau} \\ \frac{dx^*}{d\delta} \\ \frac{dk^*}{d\delta} \end{pmatrix} = \frac{1}{|\mathbf{H}|} \begin{pmatrix} k\pi_{kk} - x\pi_{xk} \\ x\pi_{kk} - k\pi_{xk} \\ \frac{c'(k)}{\delta}\pi_{xk} \\ -\frac{c'(k)}{\delta}\pi_{xx} \end{pmatrix} = \frac{1}{|\mathbf{H}|} \begin{pmatrix} -k\frac{c'(k)}{\delta} \\ kx(p''(x)x + 2p'(x)) \\ -\frac{c'(k)}{\delta^2}kxS''(kx) \\ -\frac{c'(k)}{\delta^2}k(p''(x)x + 2p'(x) - kS''(kx)) \end{pmatrix},$$

where, as before,

$$\begin{aligned}
|\mathbf{H}| &\equiv \pi_{xx}\pi_{kk} - \pi_{xk}^2 \\
&= -k(p''(x)x + 2p'(x) - kS''(kx)) \left( x^2S''(kx) + \frac{c''(k)}{\delta} \right) \\
&\quad - \left( p'(x)x + p(x) - (\tilde{\alpha}_1 + \tau) - S'(kx) - kxS''(kx) \right)^2.
\end{aligned}$$

At the optimum, this expression simplifies since  $p'(x)x + p(x) - (\tilde{\alpha}_1 + \tau) - S'(kx) = 0$ .

By the second-order condition,  $|\mathbf{H}| > 0$ , so  $\frac{dk^*}{d\tau} < 0$ ,  $\frac{dx^*}{d\tau} < 0$ , and  $\frac{dk^*}{d\delta} > 0$ ,  $\frac{dx^*}{d\delta} > 0$ . Therefore, total import volume increases with  $\delta$  and falls with  $\tau$ :  $\frac{d(k^*x^*)}{d\tau} < 0$  and  $\frac{d(k^*x^*)}{d\delta} > 0$ . Import *value* also moves in the same direction:

$$\begin{aligned}
\frac{d(k^*x^*p(x^*))}{d\tau} &= k^*(p(x^*) + x^*p'(x^*))\frac{dx^*}{d\tau} + x^*p(x^*)\frac{dk^*}{d\tau} < 0 \\
\frac{d(k^*x^*p(x^*))}{d\delta} &= k^*(p(x^*) + x^*p'(x^*))\frac{dx^*}{d\delta} + x^*p(x^*)\frac{dk^*}{d\delta} > 0.
\end{aligned}$$

□

*Derivation of Cross-Partials*  $\frac{d^2k^*}{d\tau d\delta}$  and  $\frac{d^2x^*}{d\tau d\delta}$ . To evaluate the cross-partial terms, we apply Young's Theorem,  $\frac{d^2k^*}{d\tau d\delta} = \frac{d^2k^*}{d\delta d\tau}$  (and similarly for  $x^*$ ).

First consider the effect of a higher  $\delta$  on the quantity

$$\frac{dk^*}{d\tau} = \frac{-2bx^*}{(2b - k^*\sigma) \left( \frac{1}{\delta} - (x^*)^2\sigma \right) - k^*(x^*\sigma)^2}.$$

When  $\delta$  increases,  $k^*$  and  $x^*$  both increase, raising the absolute value of the numerator (which remains negative). The denominator falls, but remains positive, as long as the second-order conditions are satisfied, so for interior solutions,  $\frac{d^2k^*}{d\delta d\tau} < 0$ : the better is the chaining technology, the larger is the impact of trade liberalization on chain size.

Next, consider what happens to the quantity

$$\frac{dx^*}{d\delta} = \frac{\frac{1}{\delta^2}(k^* - 1)x^*\sigma}{(2b - k^*\sigma)\left(\frac{1}{\delta} - (x^*)^2\sigma\right) - k^*(x^*\sigma)^2}$$

when  $\tau$  falls. Since  $\frac{dk^*}{d\tau} < 0$  and  $\frac{dx^*}{d\tau} < 0$ , the numerator increases when  $\tau$  falls; the denominator falls, but remains positive as long as the second-order conditions continue to be satisfied.

Therefore  $\frac{d^2x^*}{d\delta d\tau} < 0$ .<sup>36</sup> □

## B Data Appendix

We use BLS price indices for the years 1984-2003 to compute apparel CPI inflation in 23 geographic markets (MSAs) (denoted  $\Delta P_{it}$ ) as the year-to-year log change in each MSA's apparel CPI. The BLS price indices can be obtained from the BLS web site, <http://www.bls.gov/cpi/>.

The MSAs used in the analysis are: Anchorage; Atlanta; Boston-Brockton-Nashua; Chicago-Gary-Kenosha; Cincinnati-Hamilton; Cleveland-Akron; Dallas-Fort Worth; Denver-Boulder-Greeley; Detroit-Ann Arbor-Flint; Honolulu; Houston-Galveston-Brazoria; Kansas City; Los Angeles-Riverside-Orange County; Miami-Fort Lauderdale; Milwaukee-Racine; Minneapolis-St. Paul; Philadelphia-Wilmington-Atlantic City; Pittsburgh; Portland-Salem; St. Louis; San Diego; San Francisco-Oakland-San Jose; Seattle-Tacoma-Bremerton.<sup>37</sup>

We also compute Wal-Mart's market share in each MSA each year, denoted  $WMshare_{it}$ , as the ratio of the number of existing Wal-Mart stores in the MSA to the number of all retail establishments specializing in apparel or "general merchandise" sales. The relevant number of retail establishments is computed by adding up the number of establishments across all counties within each MSA for SIC codes 5300 (general merchandise) and 5600 (apparel) for

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<sup>36</sup>Once  $\delta$  reaches a sufficiently high value,  $k^* = N$  and  $x^* = \frac{a - \alpha_1 - \tau}{2b + \sigma N}$ . Declines in  $\tau$  from that point on do not affect  $k^*$ , but  $x^*$  continues to increase, albeit at a constant rate.

<sup>37</sup>The results are not sensitive to the inclusion or exclusion of the New York-Northern New Jersey-Long Island MSA, which had no Wal-Mart stores throughout the period.

1985-1997, and for NAICS codes 452 and 448 thereafter, from County Business Patterns.<sup>38</sup>

The number of existing Wal-Mart stores in each MSA each year come from available historical lists of Wal-Mart store locations. For 1985-1993 we use the annual publication *Directory of Discount Stores* published by Chain Store Guides; for 1994-2003 we use the Wal-Mart editions of the road atlas published by Rand McNally, which contain complete store lists (see Basker (2005a,b) for details on the data set construction). We supplement these lists with data from press releases, available on Wal-Mart's web site, about more recent store openings.<sup>39</sup>

Finally, we obtain the apparel import price index from the BLS web site, <http://www.bls.gov/mxp/>. We use the import price index for Standard International Trade Classification (SITC) code 84, and for end-use classification code 400. We compute the import inflation rate (denoted  $\Delta P_t^m$ ) for both indices using December-to-December log changes in the value of the index.

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<sup>38</sup>Despite the shift from SIC to NAICS after 1997, we find no break in the numbers of establishments before and after this shift, suggesting that the mapping from SIC to NAICS is fairly straightforward for these two classifications. County Business Patterns data can be obtained from <http://www.census.gov/epcd/cbp/view/cbpview.html>.

<sup>39</sup>The press releases are available from <http://www.walmartstores.com/wmstore/wmstores/HomePage.jsp>. Special care needs to be taken using them, however, since new openings, store renovations, and conversions of "discount stores" to "supercenters" are often not distinguished in the releases. To circumvent this problem we match all press release data against the list of existing stores to ensure that we do not double count stores.

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Table 1. Regression Results for Consumer Price Inflation

	SITC Import Inflation		End-Use Import Inflation	
	(1)	(2)	(3)	(4)
$\Delta P_t^m$	0.4331 (0.0722)*** (0.0439)*** (0.1820)**	0.3036 (0.0848)*** (0.0505)*** (0.1769)	0.5123 (0.0687)*** (0.0423)*** (0.1376)***	0.3657 (0.0835)*** (0.0502)*** (0.1326)**
WMshare <sub>it</sub>		-1.2754 (0.3010)*** (0.3739)*** (0.4254)***		-1.1159 (0.3482)*** (0.3574)*** (0.3961)**
$\Delta P_t^m \cdot \text{WMshare}_{it}$		24.3187 (14.0860)* (6.8626)*** (9.5233)**		25.9046 (13.2896)* (9.8475)** (11.9003)**
Observations	437	437	437	437

Note: Standard errors in parentheses, respectively: unclustered, clustered by MSA, clustered by year. \* significant at 10%; \*\* significant at 5%; \*\*\* significant at 1%

Table 2. Growth of Retail Chains, 1948-1997<sup>a</sup>

	Chains' Share of All			Large Chains' Share of All Chains'		
	Firms	Stores	Sales	Firms	Stores	Sales
1948		9.2%	29.6%		27.2%	41.6%
1954		9.7%	30.1%		26.5%	41.8%
1958		10.2%	33.7%		27.5%	42.4%
1963	2.85%	12.9%	36.6%	0.44%	31.8%	43.2%
1967	2.16%	12.5%	39.8%	0.60%	37.6%	46.7%
1972	2.62%	15.2%	45.2%	0.68%	40.2%	55.8%
1982	3.24%	20.9%	52.3%	0.74%	45.5%	56.5%
1992	4.95%	33.6%	58.2%	1.02%	51.5%	58.8%
1997 <sup>b</sup>	5.12%	37.5%	61.2%	1.32%	56.6%	61.0%

Source: authors' calculations from Census of Business (various years) and Census of Retail Trade (various years)

<sup>a</sup> Chains include multi-unit retailers with more than one unit; large chains include chains with 101+ stores for 1948-1972, 100+ stores in 1982-1997

<sup>b</sup> Classification by SIC 1948-1992, NAICS thereafter.

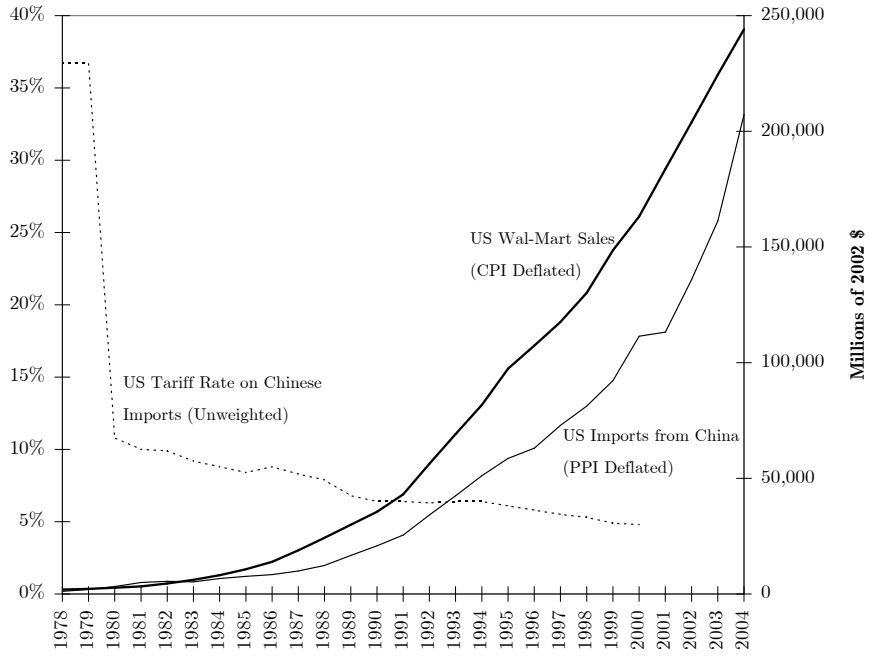


Figure 1. U.S. Tariff on Chinese Imports, U.S. Imports from China and U.S. Wal-Mart Sales

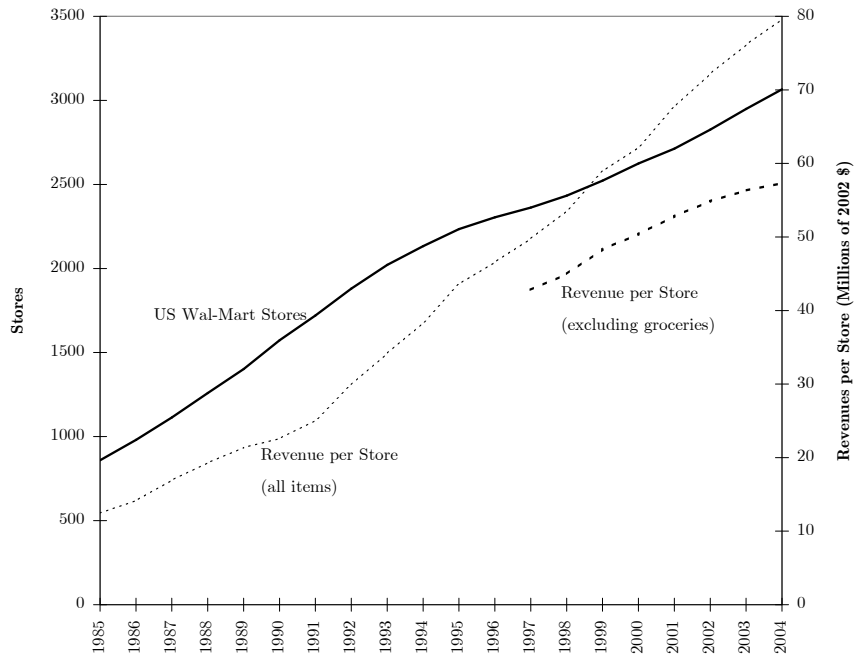


Figure 2. Wal-Mart's Growth: Stores and Average Sales per Store, 1985-2004

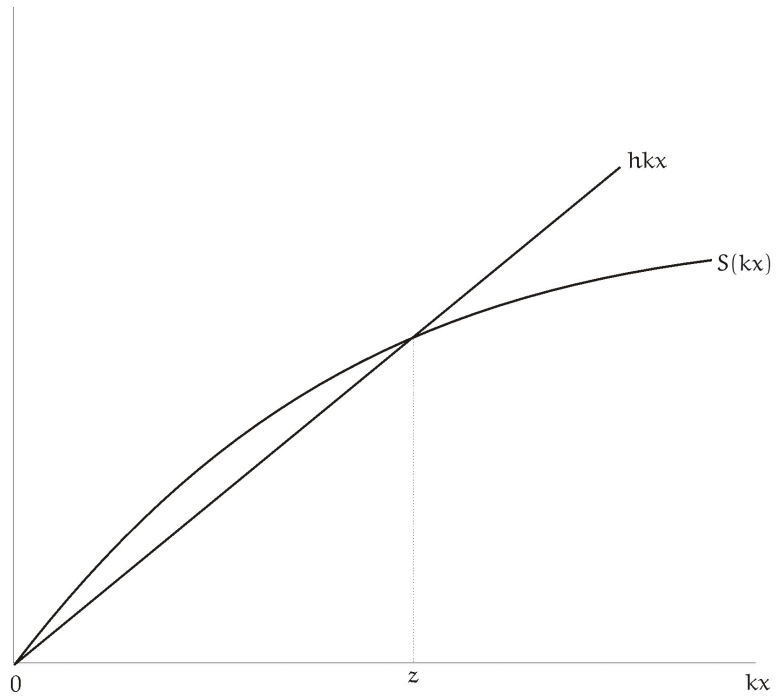


Figure 3. Marketing Technologies

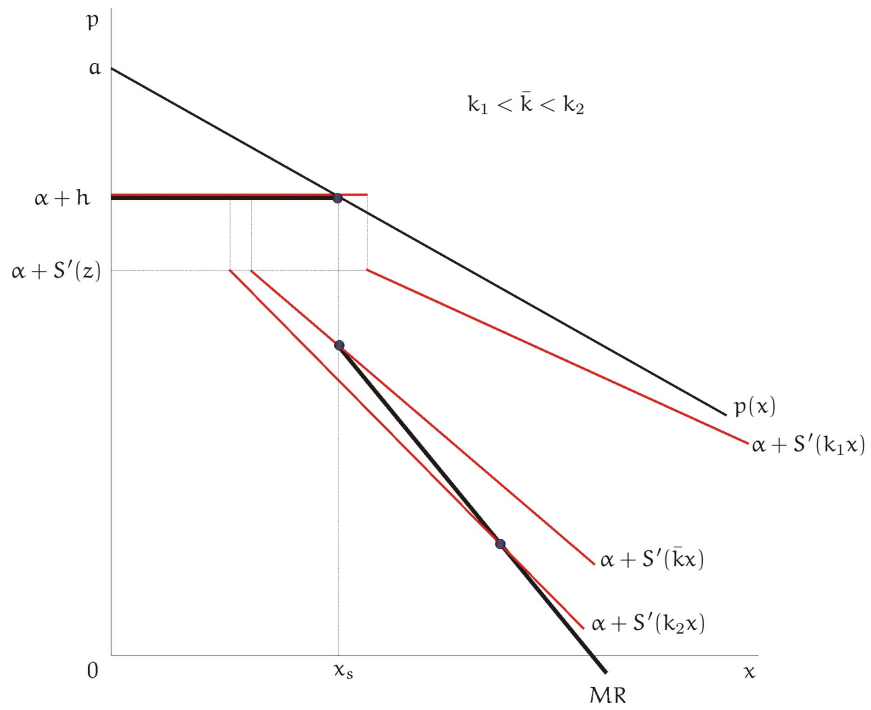


Figure 4. Determination of  $x^*(k)$

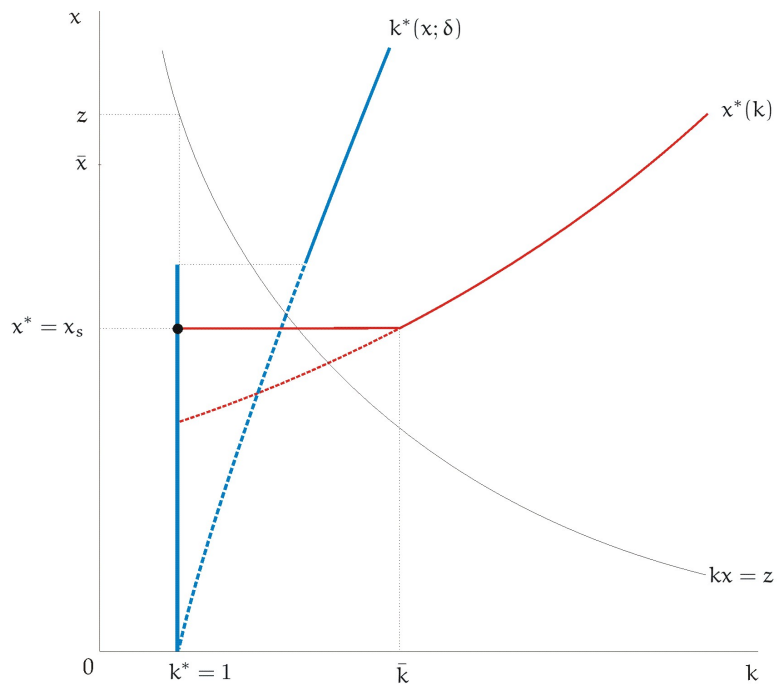


Figure 5. Equilibrium Chain Size and Quantity for Low  $\delta$

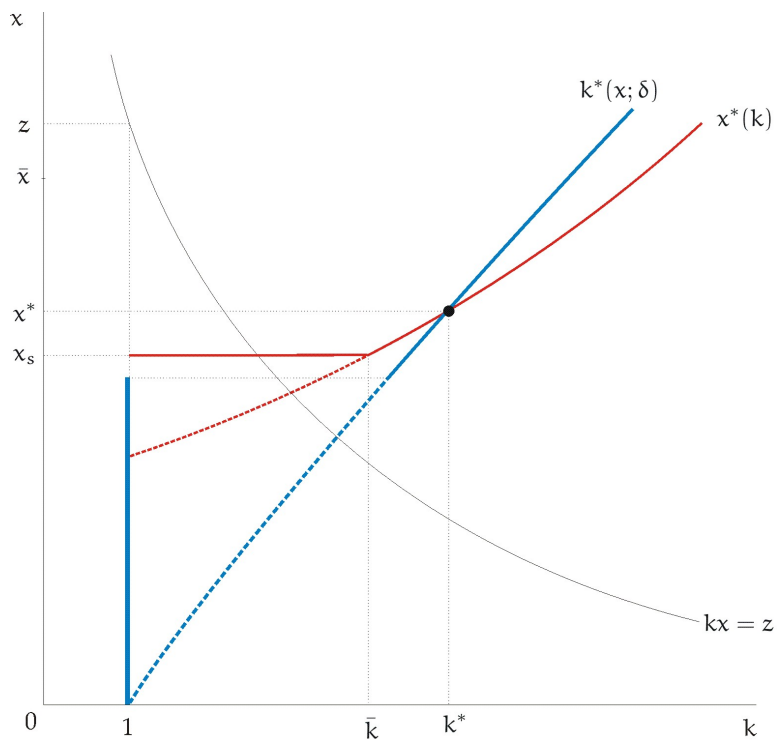


Figure 6. Equilibrium Chain Size and Quantity for High  $\delta$

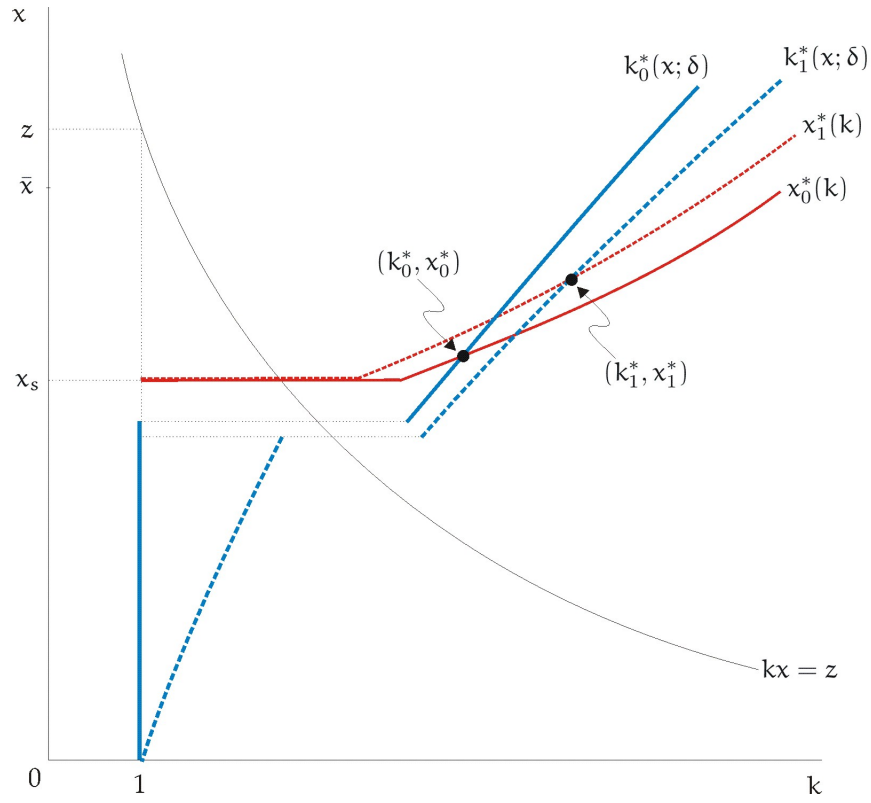


Figure 7. Equilibrium Chain Size and Quantity: Domestic vs. Foreign Production

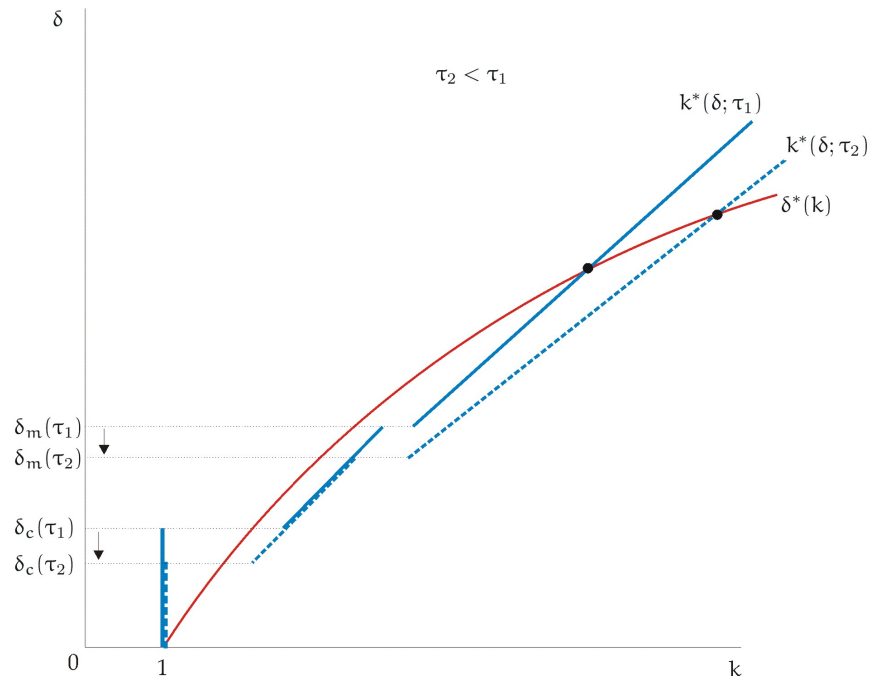


Figure 8. Endogenous Chaining Technology

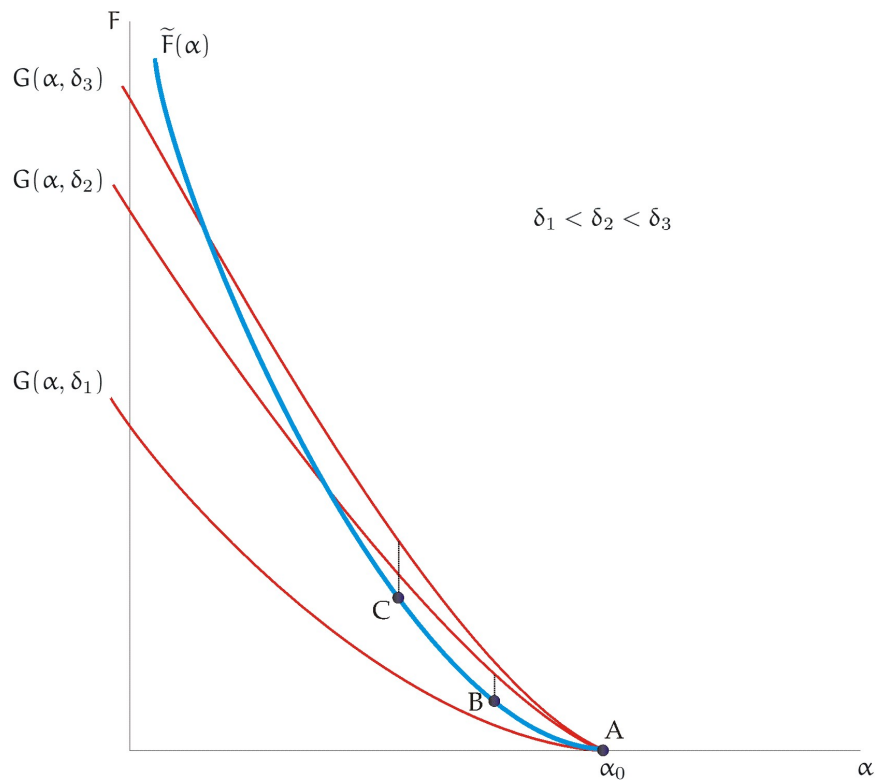


Figure 9. Location of Production and Chaining Technology