Shipping the Good Horses Out*

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August 2010

Abstract

This paper formalizes the Allen-Alchian (1964) theorem in a vertically-differentiated good model and show that the effect of a fixed transportation cost regardless of quality tilts the importing country's demand towards the consumption of higher quality goods. The model extends the theorem in showing a new prediction: that the size of this effect depends on the conditions of the importing country. Specifically, if the importing country is endowed with the imported goods of similar quality mix, the Allen-Alchian effect is even stronger. We also show that the importing country's market size and preferences matter to the strength of the effect. Using auction data of Australian thoroughbred yearlings, we confirm that better horses are "shipped out" further. Furthermore, consistent with the model's prediction, the size of the Allen-Alchian effect depends on the endowment of the importing places.

*We would like to thank Rondy Wong and William Tsang for excellent research assistance.

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1 Introduction

California ships apples to various states. Regardless of the quality, shipping an apple to any part of the east coast costs roughly the same. The Allen-Alchian (1964) theorem states that relatively more good apples will be "shipped out" because the fixed transportation cost lowers the relative price of good apples. It is, however, hard to imagine that different states in the east coast all import the same quality mix of apples from California. Which states import relatively more good Californian apples? In other words, even though the transportation cost of shipping an apple is roughly the same, its effect of tilting the consumption to higher quality apples may differ. What are the factors that determine the size of such an effect? It is a question the literature has not explored.

One intuitive factor is that some states in the east coast grow its own apples. This should affect the quality mix of the imported Californian apples. Consider time dimension in the context of California-Viriginia apple trade. While Viriginia does not grow its own apple, the added fixed transportation cost raises the relative price of bad apples and therefore tilts Virginia's demand towards good apples. If some farmers bring seeds to Virginia and the state starts producing a small amount of its own bad apples, it is reasonable to expect that this further tilts the trade-flow towards good apples. Other factors that may affect the size of the effect include the market size, the income level and the preferences of the importing states.

We formalize the Allen-Alchian effect in a two-country vertically-differentiated goods model. The model allows us to investigate how these factors interact with the Allen-Alchian effect. Three conclusions follow. First, the size of the effect depends on the endowment of the importing states. If the importing country is endowed with the imported goods of roughly the same quality mix relative to the exporting country, then the size of the effect is even bigger relative to the case in which the importing country has no endowment. Second, changing the market size of the importing country changes the quality mix of the trade flow too, but no such change is derived if the importing country has no endowment. Third, if the importing country has a higher preferences for good apples, the quality mix of the trade flow is higher.

Instead of focusing on apples, we use thoroughbred yearlings (horses specially bred for racing) as our empirical context.[1] We use Australian thoroughbred yearlings auction data to provide consistent empirical evidence. The data has two unique features. First, the hammer price is a good proxy of the underlying quality of the yearling. Second, the data set identifies the buyers and their locations. Therefore, we know exactly what horses are shipped from which part of Australia to which part of the world.

The paper complements the literature on formalizing and testing the Allen-Alchian theorm. CITE THEM CLEVERLY.

Hummels and Skiba (2004) show that the Allen-Alchian theorem is important in explaining international trade patterns. The paper also relates closely to the boarder trade literature on explaining the quality mix of trade flows.

Transportation cost: Hummels and Skiba (2004), Hummels (2007), Lugovskyy and Skiba (2010),

Income distribution: Choi, Hummels and Xiang (2009), Hallak (2006), Baier and Bergstrand (2001), Lugovskyy and Skiba (2010).

2 The model

2.1 SUPPLY

Horses are of two types: high-quality (H) and low-quality (L).

There are two countries, a and b. Both of them are endowed with the two types of horses.

[1] Apples imports can be broken down by states. We do not, however, observe the "quality" of apples shipped across states. Instead, we only observe the average per-unit value across state pairs. Instead, we observe individual prices of horses and it is a good proxy for the quality of horses. Beyond data limitations, using thoroughbred yearlings has several merits over apples. People consume apples in different ways. For instance, instead of eating the whole apple, we can make apple juices out of fresh apples. We can mix apples with other fruits for salad. But thoroughbred yearlings are used only for the purposes of horse-racing. Owners neither use them for horse-powering nor farming.

The total endowment of high-quality and low-quality horses are $\frac{1}{2}$ and $\frac{1}{2}$, respectively. Of the total endowment, a small amount, $\lambda\varepsilon$ of high-quality horses and ε of low-quality horses, are endowed in country b. The remaining $\frac{1}{2} - \lambda\varepsilon$ of high-quality horses and $\frac{1}{2} - \varepsilon$ of high-quality horses are endowed in country a. Therefore, the endowment ratio of high-to-low quality horses are $\frac{\frac{1}{2}-\lambda\varepsilon}{\frac{1}{2}-\varepsilon}$ for country a and $\frac{\lambda\varepsilon}{\varepsilon} = \lambda$ for country b. Country a is relatively more endowed with high-quality horses than country b if and only if $\lambda < 1$.

Shipping a horse from one country to another country cost $t > 0$, regardless of the quality of the horse.

2.2 DEMAND

Both country a and b have the same population of potential buyers normalized to 1. The total population of potential buyers is therefore of size 2. Given that the total supply of horses, including both high-quality and low-quality ones, is 1, the potential demand exceeds the supply. In equilibrium, therefore, some people must be buying no horse.

Buyers are heterogenous. The utility function of an θ-type buyer is:

$$u(\theta, p') = \begin{cases} 2\theta - p' & \text{if} \quad \text{buy high-quality} \\ \theta - p' & \text{if} \quad \text{buy low-quality} \\ 0 & \text{if} \quad \text{not buy} \end{cases},$$

where p' is the gross price the buyer pays for the horse, and $\theta \in [0, 1]$.[2] The gross price p' is equal to p, the price of the horse, if the buyer buys from his own country. If he buys from the other country, the gross price p' is equal to $p + t$. The higher is θ, the more value the buyer

[2] This utility specification can also be generated by consumers having identical ordinal preferences but differ only in their income. This is documented in footnote 1 of Chapter 2 of Tirole (1988). In the theoretical trade literature, Flam and Helpman (1987) uses the utility function for vertically-differentiated products $u(y, z) = ye^{\alpha z}$, where y is the numeraire, and the consumer only consumes one unit of the vertically-differentiated product of quality z. We can interpret $z = 0$ as not consuming horses in their utility specification. And $z = z^l$ as consuming a low-quality horse, and $z = z^h$ as consuming a high-quality horse. The aggregate utility a consumer can derive then depends on the equilibrium y, which is analogous to our setup of θ. Choi, Hummels, and Xiang (2009) also uses this utility specification to study how income distribution connects with quality distribution of imports.

derives from a horse. This utility specification also implies the value of high-quality horse is twice as high as that of a low-quality one for every buyer, except for those with $\theta = 0$.

Buyers in each country are distributed uniformly across the range of θ.

2.3 EQUILIBRIUM

Equilibrium is a quadruple of prices $\left(p_a^H, p_a^L, p_b^H, p_b^L\right)$, where subscripts denote country and superscripts denote horse quality, such that the quantity demanded is equal to the quantity supplied for each type of horses. Given $\left(p_a^H, p_a^L, p_b^H, p_b^L\right)$, every buyer is utility-maximizing.

2.3.1 Equilibrium analysis

Since ε is small, the trade flow, if any, should go from country a to country b. The idea is that if rice is abundant in Thailand but Hong Kong just produces a little bit of rice, we expect Thailand exports rice to Hong Kong, but not the other way around.[3] If shipping horses is prohibitively costly (e.g., $t \approx \infty$), there is no trade among countries. On the other hand, if t is small *enough*, trade from country a to country b is expected. We take the latter case.

Country a's demand: Since trade flows from country a to country b, the only relevant prices for country a's buyers are p_a^H and p_a^L. Take $p_a^H > p_a^L$, i.e., horses of higher quality command higher prices. Buyers of high enough θ would opt for high-quality horses, buyers of intermediate θ would opt for low-quality horses, and buyers of low enough θ would opt out from horse-buying. Define two thresholds, $\widetilde{\theta}_a$ and $\widehat{\theta}_a$, such that in country a, buyers of type $\theta \in \left[\widetilde{\theta}_a, 1\right]$ buys high-quality horses, buyers of type $\theta \in \left[\widehat{\theta}_a, \widetilde{\theta}_a\right]$ buys low-quality horses, and buyers of type $\theta \in \left[0, \widehat{\theta}_a\right]$ buys no horse. Define two thresholds (denoted $\widetilde{\theta}_b$ and $\widehat{\theta}_b$) similarly for country b.

[3]We ignore the case of bilateral two-way trade flow such as the following case: Canada exports timber to the States in the west coast, but imports timber from the States in the east coast.

At threshold $\widetilde{\theta}_a$, the marginal buyer should be indifferent between buying a high-quality horse and a low-quality horse, i.e., $2\widetilde{\theta}_a - p_a^H = \widetilde{\theta}_a - p_a^L$.

At threshold $\widehat{\theta}_a$, the marginal buyer should be indifferent between buying a low-quality horse and not buying, i.e., $\widehat{\theta}_a - p_a^L = 0$.

Rearranging terms gives

$$\widetilde{\theta}_a = p_a^H - p_a^L$$

and

$$\widehat{\theta}_a = p_a^L.$$

Since buyers are distributed uniformly from 0 to 1, the demand for high-quality horses is $1 - \widetilde{\theta}_a$, and that for low-quality horses is $\widetilde{\theta}_a - \widehat{\theta}_a$.

Country b's demand: Country b's buyers buy from both countries. To any buyer, a horse is a horse, irrespective of where it comes from. This implies a relationship among prices. Specifically, p_b^L has to be equal to $p_a^L + t$, and p_b^H has to be equal to $p_a^H + t$. If not, then arbitrage opportunities exist.

At threshold $\widetilde{\theta}_b$, the marginal buyer should be indifferent between buying a high-quality horse and a low-quality horse, i.e., $2\widetilde{\theta}_b - p_b^H = \widetilde{\theta}_b - p_b^L$.

At threshold $\widehat{\theta}_b$, the marginal buyer should be indifferent between buying a low-quality horse and not buying, i.e., $\widehat{\theta}_b - p_b^L = 0$.

Rearranging terms and substituting $p_b^L = p_a^L + t$ and $p_b^H = p_a^H + t$ give

$$\widetilde{\theta}_b = p_a^H - p_a^L$$

and

$$\widehat{\theta}_b = p_a^L + t.$$

Two points are noteworthy. First, both countries have the same threshold that divides the consumption of high- versus low-quality horses (i.e., $\widetilde{\theta}_b = \widetilde{\theta}_a$). Second, country b's threshold that divides the consumption of low-quality horses versus not buying is pushed upward by the transportation cost, t, relative to that of country a (i.e., $\widehat{\theta}_b = \widehat{\theta}_a + t$).

Country b's demand for high-quality horses from country a is $1 - \widetilde{\theta}_b - \lambda\varepsilon$, instead of $1 - \widetilde{\theta}_b$ because exactly $\lambda\varepsilon$ of country b's high-quality horse buyers buy from its own country. Similarly, country b's demand for low-quality horses from country a is $\widetilde{\theta}_b - \widehat{\theta}_b - \varepsilon$, instead of $\widetilde{\theta}_b - \widehat{\theta}_b$. Who exactly buy from country a and who from country b, however, is not a substantive matter.

Market-clearing: Market-clearing requires the quantities demanded equal the quantities supplied for each type of horses. For country b's horses, the quantity demanded equal the quantity supplied from the above analysis already.

For country a's horses, market-clearing implies

$$\begin{aligned}\left(1 - \widetilde{\theta}_a\right) + \left(1 - \widetilde{\theta}_b - \lambda\varepsilon\right) &= \frac{1}{2} - \lambda\varepsilon, \\ \left(\widetilde{\theta}_a - \widehat{\theta}_a\right) + \left(\widetilde{\theta}_b - \widehat{\theta}_b - \varepsilon\right) &= \frac{1}{2} - \varepsilon.\end{aligned}$$

The solutions to the two equations are $p_a^H = \frac{5}{4} - \frac{t}{2}$ and $p_a^L = \frac{1}{2} - \frac{t}{2}$, which also implies $p_b^H = \frac{5}{4} + \frac{t}{2}$ and $p_b^L = \frac{1}{2} + \frac{t}{2}$. This quadruple of prices constitutes the equilibrium.

For country a, the demand for high-quality horse is $\frac{1}{4}$ (from $\theta \in \left[\frac{3}{4}, 1\right]$), and that for low-quality horse is $\frac{1}{4} + \frac{t}{2}$ (from $\theta \in \left[\frac{1}{2} - \frac{t}{2}, \frac{3}{4}\right]$).

For country b, the demand for country a high-quality horse is $\frac{1}{4} - \lambda\varepsilon$ (from $\theta \in \left[\frac{3}{4}, 1\right]$ minus country b's own supply $\lambda\varepsilon$), and that for low-quality horse is $\frac{1}{4} - \frac{t}{2} - \varepsilon$ (from $\theta \in \left[\frac{1}{2} + \frac{t}{2}, \frac{3}{4}\right]$ minus the within-country supply ε).

2.4 The Allen-Alchian theorem

Country b's relative demand of high- versus low-quality horses from country a is $\frac{\frac{1}{4}-\lambda\varepsilon}{\frac{1}{4}-\frac{t}{2}-\varepsilon}$. This ratio implies two Propositions.

Proposition 1. *If country b is not endowed with horses ($\varepsilon = 0$), country b consumes relatively more high-quality horses relative to country a does if the transportation cost is positive ($t > 0$). Such a relative consumption difference is larger the larger is the transportation cost (t increases).*

Proposition 2. *If country b is endowed with a small amount of horses ($\varepsilon > 0$), then the relative consumption difference among the two countries depends on country b's endowment ratio. (i) If country a is relatively well-endowed with high-quality horses ($\lambda \leq 1$), the relative consumption difference is even larger than that in the case with no endowment. (ii) If country b is relatively well-endowed with high-quality horses ($\lambda > 1$), the relative consumption difference is smaller than that in the case with no endowment.*

Part (i) is due to the ratio $\frac{\frac{1}{4}-\lambda\varepsilon}{\frac{1}{4}-\frac{t}{2}-\varepsilon}$ increasing in ε when $\lambda \leq 1$. In contrast, part (ii) is due to the ratio decreasing in ε when $\lambda > 1$.

Proposition 2 is a new but intuitive idea not previously explored. The size of the Shipping-the-good-apples-out effect depends on the endowment of the importing market. Proposition 1 implies if California (country a) ships apples to New York (country b), California consumes relatively more bad apples than New York does because of the transporation cost when New York does not grow its own apples. This is the classic Allen-Alchian theorem.

Proposition 2 implies that if New York does grow its own apple, but California produces relatively more good apples than New York does, then the relative consumption difference is even bigger (i.e., relatively more good Californian apples are "shipped out" than in the case when New York does not grow its own apples). On the other hand, if New York produces relatively more good apples than California does, the relative consumption difference is smaller (i.e., relatively fewer good Californian apples are "shipped out" than in the case when New York does not grow its own apples).

2.4.1 Two extensions:

This section extends the model to incorporate market size difference and preferences differences.

Market size differences To incorporate market size differences, modify the model by setting the size of country a as 1 but the size of country b as γ. Two modifications follow. First, country b's demand for high-quality horses from country a is $\gamma(1-\widetilde{\theta}_b)-\lambda\varepsilon$, instead of $1-\widetilde{\theta}_b-\lambda\varepsilon$ when there is no size difference. Second, country b's demand for low-quality horses from country a is $\gamma(\widetilde{\theta}_b-\widehat{\theta}_b)-\varepsilon$, instead of $\widetilde{\theta}_b-\widehat{\theta}_b-\varepsilon$.

The market-clearing conditions now become

$$\begin{aligned}\left(1-\widetilde{\theta}_a\right)+\left(\gamma(1-\widetilde{\theta}_b)-\lambda\varepsilon\right) &= \frac{1}{2}-\lambda\varepsilon,\\ \left(\widetilde{\theta}_a-\widehat{\theta}_a\right)+\left(\gamma(\widetilde{\theta}_b-\widehat{\theta}_b)-\varepsilon\right) &= \frac{1}{2}-\varepsilon.\end{aligned}$$

Substituting and rearranging terms give $p_a^H=\frac{4\gamma-2t\gamma+1}{2(1+\gamma)}$ and $p_a^L=\frac{\gamma(1-t)}{1+\gamma}$, which also implies $p_b^H=\frac{2t+4\gamma+1}{2(\gamma+1)}$ and $p_b^L=\frac{t+\gamma}{1+\gamma}$.

For country a, the demand for high-quality horse is $\frac{1}{2(1+\gamma)}$ (from $\theta\in\left[\frac{1+2\gamma}{2(1+\gamma)},1\right]$), and that for low-quality horse is $\frac{1+2t\gamma}{2(1+\gamma)}$ (from $\theta\in\left[\frac{\gamma(1-t)}{1+\gamma},\frac{1+2\gamma}{2(1+\gamma)}\right]$).

For country b, the demand for country a's high-quality horses is $\frac{\gamma}{2(1+\gamma)}-\lambda\varepsilon$ (from $\theta\in\left[\frac{1+2\gamma}{2(1+\gamma)},1\right]$ multiplied by the size γ, and then minus country b's own supply $\lambda\varepsilon$), and that for low-quality horses is $\frac{\gamma(1-2t)}{2(1+\gamma)}-\varepsilon$ (from $\theta\in\left[\frac{t+\gamma}{1+\gamma},\frac{1+2\gamma}{2(1+\gamma)}\right]$ multiplied by the size γ, and then minus the within-country supply ε).

Country b's relative demand of high- versus low-quality horses from country a is $\frac{\frac{\gamma}{2(1+\gamma)}-\lambda\varepsilon}{\frac{\gamma(1-2t)}{2(1+\gamma)}-\varepsilon}$.

The first derivative of this ratio with respect to country b's size γ is $-\frac{(2\varepsilon)((1-\lambda)+2t\lambda)}{(2\varepsilon-\gamma+2t\gamma+2\gamma\varepsilon)^2}$. If $\lambda\leq\frac{1}{1-2t}$, then this derivative is negative. It implies that when increasing country b's market size lowers its relative demand for high-quality horses from country a. In contrast, if

$\lambda > \frac{1}{1-2t}$, then increasing country b's market size raises its relative demand for high-quality horses from country a.

The analogy is that if California ships apples to both New York and Virginia, even if the distribution of buyers' preferences of apples are the same and the good-bad apple endowment ratios for all the three states are roughly equal, California is expected to ship relatively more good apples to Viriginia (a smaller market) than to New York (a bigger market).

Two points are noteworthy. First, this implication holds only if $\varepsilon > 0$. Suppose $\varepsilon = 0$, as in the old Allen-Alchian context without considering the endowment of the importing places, then market size differences do not induce any difference in the size of the Allen-Alchian effect. Second, this result does not come from the possibility that a larger market economizes transportation cost of a particular product.

Preferences differences To incorporate preferences differences, restore the size of both countries as 1. Modify the model by setting country a's buyers as distributed uniformly from 0 to 1, whereas country b's buyers are distributed uniformly from $0 + \sigma$ to $1 + \sigma$. We now need one modification. Country b's demand for high-quality horses from country a is $(1 + \sigma - \widetilde{\theta}_b) - \lambda\varepsilon$, instead of $1 - \widetilde{\theta}_b - \lambda\varepsilon$ when the distribution of country b's buyers does not shift. Country b's demand for low-quality horses from country a, however, remains unchanged at $(\widetilde{\theta}_b - \widehat{\theta}_b) - \varepsilon$.

The market-clearing conditions now become

$$\begin{aligned} \left(1 - \widetilde{\theta}_a\right) + \left((1 + \sigma - \widetilde{\theta}_b) - \lambda\varepsilon\right) &= \frac{1}{2} - \lambda\varepsilon, \\ \left(\widetilde{\theta}_a - \widehat{\theta}_a\right) + \left(\widetilde{\theta}_b - \widehat{\theta}_b - \varepsilon\right) &= \frac{1}{2} - \varepsilon. \end{aligned}$$

Substituting and rearranging terms, we have $p_a^H = \frac{5}{4} - \frac{t}{2} + \sigma$ and $p_a^L = \frac{1}{2} - \frac{t}{2} + \frac{\sigma}{2}$. This also implies that $p_b^H = \frac{5}{4} + \frac{t}{2} + \sigma$ and $p_b^L = \frac{1}{2} + \frac{t}{2} + \frac{\sigma}{2}$.

For country a, the demand for high-quality horses is $\frac{1}{4} - \frac{\sigma}{2}$ (from $\theta \in \left[\frac{3}{4} + \frac{\sigma}{2}, 1\right]$), and that for low-quality horses is $\frac{1}{4} + \frac{t}{2}$ (from $\theta \in \left[\frac{1}{2} - \frac{t}{2} + \frac{\sigma}{2}, \frac{3}{4} + \frac{\sigma}{2}\right]$).

For country b, the demand for country a high-quality horses is $\frac{1}{4} + \frac{\sigma}{2} - \lambda\varepsilon$ (from $\theta \in \left[\frac{3}{4} + \frac{\sigma}{2}, 1 + \sigma\right]$ minus country b's own supply $\lambda\varepsilon$), and that for low-quality horses is $\frac{1}{4} - \frac{t}{2} - \varepsilon$ (from $\theta \in \left[\frac{1}{2} + \frac{t}{2} + \frac{\sigma}{2}, \frac{3}{4} + \frac{\sigma}{2}\right]$ minus the within-country supply ε).

Country b's relative demand of high- versus low-quality horse from country a is $\frac{\frac{1}{4}+\frac{\sigma}{2}-\lambda\varepsilon}{\frac{1}{4}-\frac{t}{2}-\varepsilon}$. It implies that when country b has a stronger preference towards high-quality horses, its relative demand of high- versus low-quality horses from country a is also higher.

The analogy is that if California ships apples to both New York and Florida, even if they are roughly of the same size and the good-bad apple endowment ratios for all the three states are roughly equal, California is expected to ship relatively more good apples to New York (a relatively richer market) than to Florida.

2.5 Relationship with the existing theroetical literature

Compare our result to Borcherding and Silberberg (1978), Umbeck (1980) and Bauman (2004).

Compare our result to Lugovskyy and Skiba (2010).

3 Empirical analysis

3.1 Data

This study takes advantage of one of the few auction data sets that has the locations of the buyers: the auction data of thoroughbred yearling auctions in Australia. Our data includes ten auctions held in Australia from 2005 January to 2005 June 10th.

A yearling is a horse between one and two years of age and have never been raced before. The term 'thoroughbred' refers to the breed of horses that is specially bred for racing.[4]

[4] To claim a horse as thoroughbred, the owner does not just claim that the horse is one. It actually requires formal registration and detailing of the bloodlines, the breeding period, as well as other information in order to formally prove a horse as thoroughbred. One of the functions of the two auction houses is to make sure a thoroughbred is actually a thoroughbred.

Table 1: Basic information of the auctions

Name of Auction	Venue	Date (2005)	No. of yearlings	No. of yearlings sold	Average price(AU$)
WI Classic	Newmarket, NSW	16th-17th January	569	415	$34,792.70
WI Premier	Oaklands Vic	13th-16th February	597	451	$52,130.80
WI Australian Easter	Newmarket, NSW	29th-31st March	598	436	$207,633.00
WI Autumn	Oaklands Vic	17th-18th April	374	272	$10,495.00
WI Scone	Scone, NSW	22nd May	200	159	$12,926.90
MM Conrad Jupiters	Gold Coast, Qld	6th-12th January	1151	876	$83,717.50
MM Adelaide	Adelaide, SA	22nd-27th February	684	493	$33,856.00
MM Perth	Perth, WA	8th-11th March	505	371	$24,447.90
MM Gold Coast Premier	Gold Coast, Qld	20th-22nd March	649	413	$15,169.50
MM National	Gold Coast, Qld	9th-10th June	382	263	$27,550.40
Total			5709	4149	$59,305.60

In Australia, auction is the de facto trading platform of racing horses. There are two auction houses, the William Inglis and Son Ltd, and the Magic Millions Sales Pty Ltd (hereafter WI and MM respectively) in the market. Their major business is to profit from hosting auction events.[5] To facilitate transactions, they publish detailed information, including pedigree tables, of horses they auction.

Our data include 4,149 transactions from ten auctions in Australia in 2005.[6] Table 1 shows the distribution of yearlings sold in the auctions and the basic information of the auctions.[7] The transaction amount was substantial. The total sales of the ten auctions was roughly AUD$246 million (around USD$187 million using the 2005 June exchange rate for conversion). On average, a yearling was sold at AUD$59,305.6 (around USD$45,000). [8]

[5] William Inglis, established in Sydney in 1867, is one of the oldest and largest thoroughbred houses in Australia. It has its "Yearling Sale Series", which is comprised of five specific yearling sales every year. The Newmarket Complex in Sydney is host to the Classic Yearling Sale and the Australian Easter Yearling Sale, while the Premier and Autumn Sales are held at the Oakland Complex in Melbourne. The Scone Sale is held in Scone but has a relatively smaller scale. The Magic Million also has five main yearling auctions-the Conrad Jupiters Yearling Sale, the Perth Yearling Sale, the Adelaide Yearling Sale, the Gold Coast Premier Yearling Sale and the National Yearling Sale. Table 1 shows all of the auctions held regularly between January and June. The flagship events of these two auction houses are the Australian Easter Yearling Sale and the Conrad Jupiters Yearling Sale, respectively.

[6] Ideally, we should make inference out of the horses that were unsold in the ten auctions. But these horses were unsold because of many reasons including withdrawal by the owners, sickness, or the winning bids being lower than the reserve price. We do not, however, observe the reserve prices, as well as the reasons why a particular horse was unsold.

[7] The number of transactions fluctuate over the half year period. One reason is that breeding is seasonal (the birthdays of the horses in our data set indicate most of them were born in September and October.) Second, races are organized seasonally too. Many require horses of certain age to be eligible for participation.

[8] The average prices of the two auction houses differ. Differences in the commission structures of the two auction houses may be one of the causes. WI charges a commission of 8% for the first AUD$150,000, and the rate reduces to 6.5% thereafter for the remaining balance. MM charges a commission of 6.6% regardless of the hammer price of the yearling. Second, the distribution of the quality of horses across the auctions may not be entirely the same. Third, there is again the seasonal factor.

3.2 Why are the trading of racing horses relevant?

3.2.1 The cost of transporting horses is unlikely to be 'iceberg'

We have to establish two things. First, the economic cost of transporting a horse is non-trivial. Second, the cost of transporting is not 'iceberg.'

The horses are present in the auctions for examinations by potential buyers, their vets or their agents on their behalf. The buyer is the one who pays for transporting horses.[9]

Horses need to be registered at the state level and are not recommended to freely move around, both for the need of relevant governmental agencies administration, and for the horse owners/operators of preventing his/her horse of any risk exposure (such as viruses). For the owners, horses left freeing moving around will be subject to risk (for example, the death of the animal by catching viruses or being hit by a car). For other horse owners, a horse left unattended may hurt other horses. A horse that is "in heat" may also attack other horses. In fact, horses in heat is a very hard-to-handle situation and it is recommended that all non-neutered horses are accompanied by professional trainers at all time. For yearlings, since they are under two years old and are never raced, they are non-neutered.

When moving horses to a different state, for example, for the purpose of competing in a race, sometimes it is subject to less regulations. But this may or may not be true. If a horse is from any particular part of the areas infected by cattle ticks, then it needs to be quarantined.

Moving a horse within a given state may also be subject to regulations. For instance, in New South Wales, moving a horse must be accompanied by a completed Transported Stock Statement (TSS). Similarly, a livestock waybill is needed in other states.

By law, there is also minimum animal welfare requirements anyone moving a horse is

[9] From the conditions of sales published by Inglis Point 6.2, "upon the fall of the hammer, the sole risk and responsibility for a lot shall be borne by the purchaser, who shall thereafter be responsible for all expenses incurred in respect of the lot, including care of the lot. The purchaser will be liable for stabling, agistment and transport charges for any lot not removed from Inglis' stables on the day of the sale and they may be moved to alternate stables or agistment at Inglis' discretion."
http://www.inglis.com.au/uploads/documents/COS.pdf

compulsory to compel with. The *'Model Code of Practice for the Welfare of Animals: Land Transport of Horses'* provides directions on how to safeguard the welfare of horses in transit. The *Prevention of Cruelty to Animals Act 1979* (POCTA) defines minimum standard for the keeping of all animals, including horses.

It is certainly possible to move animals, including horses across states that do not go through normal inter-states highways or major ports (sea or air). At ports and at borders of states on these inter-states highways, there are usually check points for which transporters have to make an appointment and have their horses examined. Australia is a very mountainous continent. First, it is very hard to cross the border by going through the mountains. Second, there is risk involved by doing so. Third, racing horses are eventually milked through breeding and racing. And there is no point not to have a regular registration because failing to have that will render the horse not breed-able and not eligible for races.

Cattle ticks is one of the most serious parasites of cattle in Australia and can be easily spread via horse movements.(From the NSW do's and don'ts of moving horses) Therefore, there is inter-state control of movement of horses across Australia, as well as some other livestocks. Some states impose strict restrictions, while others impose less stringent restrictions (for instance, South Australia does not require movement certifications for horses moving from other states). Vaccination proof, examination by officers within a booked appointment.

Why horse transportation cost is unlikely to be 'iceberg'? Whether the horse is a lousy horse or a horse with supreme racing potential, it can still impose substantial threat to other animals or to the environment. And pretty much all regulations regarding the transportation and registration of horses across states are *non-discriminatory*, that is, a horse of higher value does not therefore subject to more registration and other types of requirements than a horse of lower value.

Health Concerns When you are preparing your horse for transport, whether you are trailering the horse yourself or having him professionally shipped, you need to check out what health papers and vaccinations your horse needs to cross state lines or go onto a new property. Every state has different requirements, so you need to prepare for every state you are traveling through.

3.2.2 Horses are unlikely to be horizontally-differentiated

Unlike wine or paintings, horses are unlikely to be horizontally differentiated. Especially when it comes to thoroughbred yearlings. Thoroughbred is a breed specific for racing. Their builts are not suitable for other purposes like horse-powering. An owner generates revenue from a horse through winning prizes in races, or breeding them and collecting stud fee. In fact, the more likely the horse is of higher racing ability, the more money the owner can collect.[10]

To any yearlings which are auctioned and are never raced, potential buyers estimate their racing ability through their bloodlines and upon close examination of the horses at the auctions. Those with winning siblings and parents are *expected* to have higher racing ability and therefore command a higher price.

Within an auction, the auction price is likely to be a good indicator of the ranking of horses based on the racing ability. It is likely to be ordinal. But as far as cardinal is concern, it is subject to argument. We take the auction price as primarily an indication of the quality of the horse. Since one auction differ from another auction, it is unlikely that we can compare price across auctions. But we can compare price within an auction. And this is exactly what we are doing.

I can check by randomly "google" some of the sellers and make sure they are really selling in their own states. I suspect that it is because of all the stringent requirements and the fact that it is possible to sell in its own states, therefore there is no incentive for sellers themselves to move a horse around. The moving cost, therefore, would be borne by the buyers.

[10] For those horsese that prove themselves to of low racing abilities, however, they will be neutered because neutered horses are much less costly to handle and the lost potential stud fee from breeding a low-racing-ability horse is unlikely to be huge.

3.3 Variables

3.3.1 Quality measure

A unique feature of our dataset is that we can use the hammer price of a thoroughbred yearling to infer its quality. The auctions are second-price. This is because thoroughbred yearlings are specifically bred for the sole purpose of racing. The higher is the racing ability, the greater amount of revenue the owner can generate from it, and the higher is its quality. The hammer price therefore serves as a particularly accurate signal of the underlying quality.[11]

Before auctions, the two auction houses publish catalogs that contain detailed information on the involved yearlings. The auction results, including the winning bids, the buyers' identities, are also made available after the auction. The catalog includes two types of information of a yearling: a) its basic information like color, sex, birthday, lot number, the breeder, etc., and b) the comprehensive information of the yearlings' bloodline, including pedigree table, the track record of both its father, mother, grandmother, and grand grandmother. The track record of its siblings is also included.[12] Therefore, beyond prices, we can also rely on these information to infer the quality of the yearlings.

3.3.2 Other variables

The dates and locations of the ten auctions are available. The auction results also indicate the locations of the buyers. If he is a foreigner, his country is shown. If he is from Australia, the state where he comes from is shown.

[11] One may ask if different potential buyers may have different values for the same horse because they hold different belief about the potentials of horses, and different "portfolio" of horses (analogously, an oil company's stock differ in value for two persons each holding different stock portfolios). For the first point, it is no doubt possible that upon close examinations at the auction, one buyer differs from the other buyer in the belief of the racing potential of a horse. What a second-price auction systematically solicits is the evaluation of the horse for the second highest bidder. TRY TO DEFEND THIS!!!

[12] All of the siblings are from the mother's side.

Table 2: Transactions by the locations of the buyers

Buyer's Location	No. of Transactions	Average Price	Std. Dev.	Distance from Australia
Australia	3716	$56,733.66	105528.6	
Out of State	1475	$74,227.05	108667.7	
Within State	2241	$45,219.71	101807.1	
Overseas	433	$81,377.60	119029.8	
New Zealand	141	$80,113.48	125039.5	2323.822
Singapore	25	$30,940.00	19873.73	6222.044
Philippines	7	$15,000.00	11842.72	6299.685
Malaysia	51	$24,931.37	21931.49	6539.7
Hong Kong	48	$147,739.60	85831.85	7395.773
Macau	2	$237,500.00	258094	7395.773
Japan	32	$106,750.00	112831.9	7965.534
Korea	54	$12,722.22	7203.685	8430.449
South Africa	50	$90,020.00	102323.7	10779.026
USA	4	$162,000.00	172904.6	15958.048
France	4	$181,250.00	145852.4	16943.052
United Kingdom	8	$212,125.00	177821.3	17003.869
Ireland	6	$396,666.70	345277.7	17260.529
China	1	$170,000.00		18311.022

4 Empirical patterns

4.1 International versus domestic sales

Transporting horse is costly, but it is even more costly if the destination is overseas.[13] The Allen-Alchian theorem predicts that on average, horses shipped to overseas are of higher quality than horses consumed locally.

Table 2 breaks down the transactions by the locations of the buyers. Of all the sales, 433 horses were sold to overseas buyers, while 3,716 horses were sold to Australian buyers. The former number being much smaller lends support to the fact that transporting a horse internationally is more costly than transporting a horse domestically.

The average price for the 433 horses sold to overseas buyers is $81,377.6, which is larger than the average price of $56,733.66 sold to Australian buyers at 1% statistical significance level. This implies the quality mix of internationally-shipped horses is significantly higher than that of domestically-shipped. This supports the Allen-Alchian theorem.

[13] Beyond different medical certification and quarantine requirements (the Animal Export Conditions Database, 2010), transporting horses by airplanes require airplane containers sectioned into stalls. The procedures have to be complied with the Live Animals Regulation set by the International Air Transport Association. Similarly, transporting horses by ships require ships to have special tractor-trailers designed for horse shipping.

Table 3: Horses of higher quality got "shipped out" internationally

	1	2	3
Dependent variables	Price	Ln(price)	$\text{Price}_{\text{median}}$
Estimation	OLS	OLS	Quantile regression
Foreign	4,498.63	0.181***	2,500*
	[5335.810]	[0.045]	[1359.091]
Auction dummies	Yes	Yes	Yes
Observations	4149	4149	4149
R-squared	0.277	0.4647	
F-test	136.6	394.8	

Robust standard errors corrected for heteroskedasticity are reported in the brackets in Columns 1 and 2, and standard errors are reported in brackets in Column 3. $*$, $**$ and $***$ represent statistical significance at the 10% 5% and 1% level.

Among the overseas transaction, we sort the destinations by the distance from Australia. New Zealand, being the closest country from Australia, bought the most horses from among the foreign countries. The average price of all horses sold to New Zealand is higher than that sold to Australian buyers at 1% significance level. The average price, however, is not statistically significantly lower than that sold to countries other than New Zealand. We believe that this has to do with different market sizes, different preferences, and different endowment of horses among the importing countries. For instance, in terms of horse-racing, Hong Kong is a substantially bigger market than China.

As auctions were held in different dates of the year, prices may only be a good proxy of quality within an auction but not across auctions. If this is the case, focusing on the average prices across auctions may be mis-leading. We therefore run the following regression:

$$\text{Price}_{jt} = \beta \text{Foreign}_{jt} + \sum_{t=1}^{10} \gamma_t \delta_t + \text{error}_{jt}, \tag{1}$$

where Price_{jt} is the price of horse j in auction t, Foreign_{jt} is a dummy equal to 1 if the buyer is from overseas, and δ_t is auction t's dummy. The null hypothesis is that within an auction, internationally-shipped horses are of the same quality as those domestically-shipped, i.e., $\beta = 0$.

Column 1 of Table 3 shows that the null is not rejected when we use the level of the price, but it is strongly rejected at 1% significance level in Column 2 when the logarithm of the price is used as the dependent variable. Two normality tests indicate that the null hypothesis that the dependent variable is normally distributed is strongly rejected at 1% significance level if the dependent variable is the level of the price, but cannot be rejected if the logarithm of the price is used as the dependent variable.[14]

Column 3 of Table 3 shows the median quantile regression version of equation (3). The median quantile regression takes into account two doubts. First, the prices, as proxies of the quality of horses, may be ordinal but not cardinal. If this is the case, averaging across ordinal prices may be mis-leading. The median is therefore a better statistic than mean. Second, there may be horses sold at extreme prices (the most expensive horse were sold domestically at AUD$2.5 millions). The median quantile regression prevents the results from driven by such outliers. The results show that within an auction, the median price of the horse sold internationally is higher than that sold domestically. Overall, the results suggest that within an auction, higher-quality horses were "shipped out" internationally.

4.2 Australian sales: within versus across states

Do the results hold for sales from within Australia? The different requirements of horse registration and moving requirements across states within Australia means that transporting a horse from within state is less costly than transporting a horse across state. The Allen-Alchian theorem predicts that on average, horses shipped to a different state are of higher quality than horses that do not shipped across states.

Table 2 shows that of the 3,716 horses sold domestically, over 60% of them are sold to Australian buyers from within the state the auctions were held. These horses on average are priced lower than those sold across states. These figures, again, lend support to the fact that transporting a horse across state is more costly than transporting a horse from within a state.

As prices may only be a good proxy of quality within an auction, we run the following

[14]Skewness/Kurtosis tests and Shapiro-Wilk W test for normality are used.

Table 4: Horses of higher quality got “shipped out” across states

	1	2	3
Dependent variables	Price	Ln(price)	$\text{Price}_{\text{median}}$
Estimation	OLS	OLS	Quantile regression
OutState	12,774.782***	0.345***	9,000***
	[3529.091]	[0.034]	[605.301]
Auction dummies	Yes	Yes	Yes
Observations	3716	3716	3716
R-squared	0.2665	0.4686	
F-test	115.5	332.6	

Robust standard errors corrected for heteroskedasticity are reported in the brackets in Columns 1 and 2, and standard errors are reported in brackets in Column 3. $*$, $**$ and $***$ represent statistical significance at the 10% 5% and 1% level.

regression for transactions sold domestically only:

$$\text{Price}_{jt} = \beta \text{OutState}_{jt} + \sum_{t=1}^{10} \gamma_t \delta_t + \text{error}_{jt}, \qquad (2)$$

where OutState_{jt} is the dummy equal to 1 if the buyer not from the state the auction was held, and Price_{jt} and δ_t are defined as in equation (3). The null hypothesis is that within an auction, horses shipped across states are of the same quality as those that are not shipped across states, i.e., $\beta = 0$.

Table 4 shows that using either the level of the price (Column 1) or its logarithm (Column 2), the null hypothesis is strongly rejected at the 1% significance level. When we take care of outliers and the ordinal nature of prices in Column 3 using the median regression, the result is still the same.

We conclude that among the domestic sales, horses that are shipped out to different states are on average of higher quality relative to horses that are sold to the state the auction is held.

4.3 Across-states sales: states soon holding an auction

The model in Section 2 predicts that the size of the Allen-Alchian effect depends on whether the importing country is endowed with apples, and how the quality mix of the endowments differ across the exporting and importing countries. A testable hypothesis is that if the quality mix of the endowments are roughly the same, then of the larger is the endowment of the importing country, the higher is the ratio of good to bad apples shipped it imports.

The ten auctions in our data set were held at different dates. Technically, just one Australian state auctions horses at a given point in time. But among the other states, the one that will soon be holding an auction is relatively more "endowed" with horses, relative to the other states that do not have an auction as soon. For instance, if state A soon will host an auction, state A buyers coming to a state B auction has an opportunity, with a shorter wait, to be able to buy from its own state to avoid the added transportation cost due to the cross-state nature. If state C will host an auction but at a time more remote in the future than state A, state C buyers will take less of such opportunity into account because their wait is going to be longer.

Our model predicts that for the state soon to hold an auction (therefore relatively more "endowed"), the shipped horses are of higher quality as compared to those horses shipped across states to a state that do not soon hold an auction.

We construct a dummy variable, denoted Next_{jt}, that takes a value of 1 if the state the buyer comes from belong to a state that will host the next thoroughbred yearlings auction. For instance, referring to Table 1, when the MM Conrad Jupiters was held in early January at Gold Coast, Queensland, the upcoming auction was the WI Classic held in mid January at Newmarket, New South Wales. Those buyers in MM Conrad Jupiters who came from New South Wales has Next_{jt} eqaul to 1, and other domestic buyers in MM Conrad Jupiters not coming from New South Wales has Next_{jt} eqaul to 0.[15]

We run the following regression for transactions sold only to Australian buyers from

[15] The website of Magic Millions indicated that the Perth Mixed Thoroughbred Sale were held at Perth, West Australia on Jun 26, 2005. According to the Australian sales result at the Thoroughbred Breeders Australia Ltd. (2010), William Inglis & Son Ltd. held the 2005 Melbourne June Thoroughbred Sale at Oaklands, Victoria on June 29-30, 2005. Therefore, for the last auction in our data set, the MM National auction, we set Next_{jt} equal to 1 for buyers in MM National that are from both West Australia and Victoria. Setting Next_{jt} equal to 1 only for buyers in MM National that are from West Australia do not change the sign of the estimated coefficients of Table 5. The statistical significance remains the same for Columns 1 and 2 in Table 5 but the statistical significance drops to 26.3% for Column 3 for the median regression.

Table 5: Horses of higher quality got "shipped out" next

	1	2	3
Dependent variables	Price	Ln(price)	$\text{Price}_{\text{median}}$
Estimation	OLS	OLS	Quantile regression
next	17,837.673***	0.139***	2,500*
	[5212.808]	[0.052]	[1308.652]
Auction dummies	Yes	Yes	Yes
Observations	1475	1475	1475
R-squared	0.1961	0.4352	
F-test	71.67	131.4	

Robust standard errors corrected for heteroskedasticity are reported in the brackets in Columns 1 and 2, and standard errors are reported in brackets in Column 3. $*$, $**$ and $***$ represent statistical significance at the 10% 5% and 1% level.

states other than the state the auction was held:

$$\text{Price}_{jt} = \beta \text{Next}_{jt} + \sum_{t=1}^{10} \gamma_t \delta_t + \text{error}_{jt}, \tag{3}$$

where and Price_{jt} and δ_t are defined as in equation (3). The null hypothesis is that within an auction, horses shipped to a state soon to hold its own auction are of the same quality as those that are shipped to states that do not soon hold their own auctions, i.e., $\beta = 0$.

Table 5 shows that the hypothesis is strongly rejected, regardless of whether we use the price level or its logarithm as the dependent variable, or whether we use OLS or median quantile regression. It suggests that on average, horses shipped to a state soon to hold its own auction are of higher quality than those that are shipped to states that do not soon hold their own auctions. This is consistent with the predication of our model.

4.4 Robustness

Is price a bad quality measure of a horse? Do our results rely on this proxy? This section uses proxies other than the nominal prices that are more fundamental to the racing ability of horses. In particular, we use the bloodlines data available in the catalogs provided by the auction houses to construct good and bad attributes of the yearlings. Good (bad) attributes are factors that raises (lowers) a potential buyer's expectation of the yearling's expected racing ability (again, yearlings have not been raced before).

Table 6: Horses of better attributes got "shipped out"

	Buyer's location					
	Overseas	Australian	Australian		Australian from other states	
Unit: % of yearlings			Out of state	Same state	Next	not next
GOOD ATTRIBUTES						
..with champion father	34.87%	28.39%	33.08%	25.30%	38.63%	29.17%
..with champion mother	1.39%	0.32%	0.54%	0.18%	0.49%	0.58%
..with their moms raced and won first place	56.12%	58.13%	60.61%	56.49%	61.54%	59.95%
..with at least one winning sibling	53.81%	50.43%	50.10%	50.65%	53.19%	47.92%
..with a Derby-eligible father	89.61%	84.23%	86.31%	82.86%	90.83%	83.10%
..with a famous father	10.85%	9.82%	14.10%	7.01%	16.37%	12.50%
BAD ATTRIBUTES						
..who's the first baby of its mother	15.24%	18.08%	18.85%	17.58%	18.17%	19.33%
..who's mother has never raced	19.63%	18.86%	17.97%	19.46%	15.22%	19.91%
..who's mother has raced but never won	24.25%	23.01%	21.42%	24.05%	23.24%	20.14%
Unit: counts						
GOOD ATTRIBUTES						
..fathers' avg. no. of wins	5.32	5.56	5.69	5.47	5.67	5.71
..mothers' avg. no. of wins	1.88	1.73	1.79	1.69	1.82	1.76
no. of sales	433	3716	1475	2241	611	864

In Columns 5, 'Next' refers to buyer from a state that will soon host the next thoroughbred yearlings auction.

Table 6 summarizes these attributes across the different types of buyers.[16] The pattern shows that in general, we observe horses sold overseas have a higher score on good attributes and lower score on bad attributes. This pattern in general holds for horses sold across states relative to horses sold within states. For horses sold across states to a state that would soon hold its own auction relative to those across-state sales but not to a state soon holding auctions, the pattern is in general also true. The pattern suggests that our results are not driven by the particular measure of quality, i.e., price.

5 Conclusion

The Allen-Alchian theorem is an intuitive concept that the international trade literature has paid increasing attention to as some research shows it is a powerful theory in explaining the quality mix of international trade flow.

A natural extension of the theorem is to understand under what circumstances the fixed-cost Allen-Alchian effect is stronger. It is intuitive to hypothesize that the strength of the

[16]Since we are not using prices anymore, these attributes should be universal across auctions and therefore can be summarized without broken down across auctions.

effect depends on the conditions of the importing countries. This paper presents a vertically-differentiated model that allows such investigations. The model shows that whether the importing countries are endowed with the importing goods, and the quality mix of such endowments change the strength of the Allen-Alchian effect. In addition, the market sizes and the preferences of the importing countries matter too.

Using a unique thoroughbred yearlings auction data set, we avoid the problem of inferring quality mix based on an aggregate unit value. The hammer price serves as a particularly good proxy of quality of the yearling. In addition, the cost of transporting horses is unlikely to be 'iceberg.' We confirm using the data that the Allen-Alchian effect does exist, and its strength depends on the endowment of the importing places.

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