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AN EMPIRICAL CONFIRMATION OF THE ALCHIAN-ALLEN CONJECTURE

David Hummels
Alexandre Skiba

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ABSTRACT

We model demand for quality differentiated goods to derive a relationship between trade costs and the quality composition of trade. Detailed data on traded goods' prices, quantities and shipping costs for many importers and exporters are used to test these predictions. These data provide a strong rejection of the iceberg assumption on transportation costs and a strong confirmation of the classical Alchian Allen hypothesis. Within a narrowly defined commodity classification, exporters charge destination-varying prices that co-vary positively with shipping costs and negatively with tariffs. Shipping costs operate as a quantitative restriction similar to quotas.

David Hummels
Department of Economics
Krannert School of Management
Purdue University
West Lafayette, IN 47907-1310
and NBER
hummelsd@purdue.edu
Tel: 765-494-4495
Fax: 765-496-1778

Alexandre Skiba
Purdue University

I. Introduction

The presence of a per unit transactions cost lowers the relative price of high quality goods. This point was originally made by Alchian and Allen, and was described by them more colorfully as "shipping the good apples out". That is, international transportation costs lead firms to ship high quality goods abroad while holding lower quality goods for domestic consumption. Despite considerable theoretical attention, this classical proposition has not previously been examined empirically. This paper tests the Alchian Allen conjecture using a model of trade in quality differentiated goods, and extensive data on traded goods' prices, quantities and shipping costs.

We begin by modeling consumer demands for traded goods of varying quality in the presence of shipping costs. In its traditional form, the Alchian Allen hypothesis concerns the relative quality of goods shipped internationally versus domestically. We generalize this to a more readily observable case: we show that the presence of bilateral variation in per unit shipping costs will change the relative price of high and low quality goods across those bilateral pairs. As a consequence, the shares of high and low quality goods, and therefore the average observed import price, will positively co-vary with shipping costs.

Critical to this demonstration is the form of the shipping cost function. The more closely shipping costs approximate the (commonly assumed) iceberg formulation, the weaker are Alchian Allen effects. Related to this point, we also show that the Alchian Allen effect is decreasing in the size of true ad-valorem costs such as tariffs.

A major contribution of the paper lies in assembling a data set suitable for examining the hypothesis. We employ bilateral trade data from over six thousand country pairs in each of more than five thousand goods (measured at the 6-digit Harmonized System level). The data include prices, quantities, shipping costs, and ad-valorem tariffs specific to each flow. Schott (2001) and Hummels and Klenow (2001) show that trade data exhibit variation in prices across exporters for a given importer in a narrow commodity. We show that, conditional on the exporter and commodity, prices vary considerably over importers. That is, exporters appear to charge destination-varying fob ("free on board", exclusive of shipping costs) prices for the same good. A straightforward interpretation of this finding is that each exporter produces goods of varying quality within a narrowly defined commodity classification. Differences in the observed price reflect differences in the quality mix across destinations.

Our estimation proceeds in two parts. First, we estimate the shipping cost function and show that shipping costs more closely resemble per unit, rather than per value, charges. This property is necessary for shipping costs to affect the quality composition of trade. We then relate the (fob) prices of traded goods to the magnitude of shipping costs. We find that doubling shipping costs leads to a 70-143% increase in average fob prices. Shipping costs affect the quality composition of trade both across exporters, and across importers for a given exporter.

We discuss alternative interpretations of our findings, including the possibility that per unit charges lead monopolistically competitive firms to charge destination-varying markups. We show that the optimal markup follows a sign pattern identical to the Alchian-Allen effect – markups are increasing in per unit trade costs, decreasing in ad-valorem costs – but the magnitude of the effect is much too small to explain our results.

This paper relates to three distinct literatures. The idea that transactions costs may shift the relative price of high and low quality goods is not new. The theoretical literature on Alchian Allen effects has primarily focused on the conditions under which relative demands for quality depend on per unit transactions costs.[1] Our interest, and contribution, lies in an empirical identification of the Alchian Allen effect. Accordingly, we begin with a model in which these effects do occur and use it to guide our examination of the data.

Prominent in the trade literature are papers that analyze international trade quotas, quality upgrading, and the attendant welfare consequences. These papers argue that quotas lead to significant quality upgrading for the goods on which quotas are imposed. Unlike the Alchian Allen literature, there is considerable empirical support for the theory, including paper that examine: cheese, Anderson (1985); footware, Aw and Roberts (1986); Japanese cars, Feenstra (1988); and US steel imports, Boorstein and Feenstra (1991). Our empirical evidence shows that shipping costs act as a kind of quantitative restriction with effects similar to quotas. Indeed, Alchian Allen effects are arguably a more important force affecting the quality mix because shipping costs are ubiquitous and bind on all trade flows regardless of size. In contrast, quotas bind on only a select few goods, a set that should dwindle in importance as GATT/WTO rules shift member nations away from quantitative restrictions.

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[1] Theoretical examinations of the Alchian Allen conjecture include Gould and Segall (1969), Borcherding and Silverberg (1978), and Umbeck (1980). Theoretical papers examining trade quotas and quality upgrading include Falvey (1979), Rodriguez (1979), Santoni and VanCott (1980), Leffler (1991) and Herguera, Kujal, and Petrakis (2000). Barzel (1976) focuses on the link between domestic taxation and quality upgrading.

Finally, our work relates to a growing literature that measures trade costs and identifies their effect on trade. For example, recent research suggests that transportation costs play a central role in determining the quantity of trade, and the distribution of trade over partners.[2] This paper examines whether and to what extent transportation also affects the quality composition of trade.

II. Relative Demands for Quality

This section examines relative demand for higher quality goods in response to a change in transportation costs. We suppose that each exporting country provides only two varieties, high and low quality, each from a competitive sector. Though we do not explicitly model the supply side[3], the assumption can be justified in several ways. The first lies behind the original "shipping the good apples out" conjecture – for reasons outside of the firm's control, production processes yield joint output of both high and low quality goods (apples), which are then priced appropriately. The second explanation is that there are two types of firms who differ in their cost of producing quality. This leads them to specialize in high and low quality goods respectively. Both stories extend easily to the case with a distribution of qualities, but this added complication adds little.

Consumers view products as differentiated by national origin, and enjoy greater utility from higher quality goods. We employ a CES utility function augmented to include quality differences, and assume that consumers take the supply of quality and the

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[2] See, for example, Hummels (2001), Limao and Venables (2000), and Finger and Yeats(1976).
[3] We re-examine our estimates in light of some supply side responses in Section IV.

associated prices as given. Denoting quantites by q, quality by λ, and indexing importers by i, exporters by j, and quality by high (H) and low (L), we have

$$(1.1) \quad U_i = \left(\sum_j \lambda_j^L \left(q_{ij}^L \right)^\theta + \lambda_j^H \left(q_{ij}^H \right)^\theta \right)^{1/\theta}$$

where $\lambda_j^H > \lambda_j^L$, and $\theta = 1 - 1/\sigma$, with σ describing the elasticity of substitution between varieties.

Suppressing quality superscripts, the price of the good facing the consumer depends on the fob price p_j and a two-part trade cost that includes both an ad-valorem tariff rate, $t_{ij} > 1$, and a per unit shipping charge f_{ij}.

$$(1.2) \quad p_{ij} = p_j t_{ij} + f_{ij}$$

Because we have assumed competitive firms, the firm's fob price is independent of the final destination. In a later section we generalize this to monopolistically competitive firms that charge a destination-varying fob price. From the consumer's first order conditions, we find :

$$(1.3) \quad \frac{q_{ij}^H}{q_{ij}^L} = \left(\frac{p_j^L t_{ij} + f_{ij}}{p_j^H t_{ij} + f_{ij}} \right)^\sigma \left(\frac{\lambda_j^H}{\lambda_j^L} \right)^\sigma$$

The relative quality demand for location j goods depends on the prices inclusive of trade costs, ratio of qualities, and elasticity of substitution. Dividing the relative prices through by the tariff we get

$$\frac{q_{ij}^H}{q_{ij}^L} = \left(\frac{p_j^L + f_{ij} / t_{ij}}{p_j^H + f_{ij} / t_{ij}} \right)^\sigma \left(\frac{\lambda_j^H}{\lambda_j^L} \right)^\sigma$$

This expression makes clear that the relative price of high and low quality goods is most affected by trade costs when the per unit freight charge is large relative to the ad-valorem tariff.

In this model, the Alchian Allen hypothesis can be seen by examining the effect of trade costs on the relative demands for high and low quality goods originating in *j*. A change in the per unit charge f results in

$$(1.4)\quad \frac{\partial\left(q_{ij}^{H} / q_{ij}^{L}\right)}{\partial f_{ij}} = \frac{\sigma}{t_{ij}}\left(\frac{\lambda_j^H}{\lambda_j^L}\right)^{\sigma}\left(\frac{p_j^L + f_{ij}/t_{ij}}{p_j^H + f_{ij}/t_{ij}}\right)^{\sigma-1}\frac{\left(p_j^H - p_j^L\right)}{\left(p_j^H + f_{ij}/t_{ij}\right)^2}$$

Assuming that it is more expensive to produce a higher quality good, $\left(p_j^H - p_j^L\right) > 0$, the sign of the derivative is positive and the share of the higher quality good is increasing in f. The size of the change depends positively on the ratio of qualities, negatively on the ratio of fob prices, and is greatest when the per unit charge f is large relative to the ad-valorem charge t.

Increasing an ad-valorem barrier has the opposite effect.

$$(1.5)\quad \frac{\partial\left(q_{ij}^{H} / q_{ij}^{L}\right)}{\partial t_{ij}} = \sigma\frac{f_{ij}}{t_{ij}^2}\left(\frac{\lambda_j^H}{\lambda_j^L}\right)^{\sigma}\left(\frac{p_j^L + f_{ij}/t_{ij}}{p_j^H + f_{ij}/t_{ij}}\right)^{\sigma-1}\frac{\left(p_j^L - p_j^H\right)}{\left(p_j^H + f_{ij}/t_{ij}\right)^2}$$

Since $\left(p_j^L - p_j^H\right) < 0$, the relative demand for the higher priced good is decreasing in the ad valorem part of the trade costs. The result that the per unit and ad-valorem costs have the opposite effect is fairly intuitive. Suppose that $f_{ij} = 0$ and all costs are ad-valorem.

$$(1.6)\quad \frac{q_{ij}^H}{q_{ij}^L} = \left(\frac{p_j^L t_{ij}}{p_j^H t_{ij}}\right)^{\sigma}\left(\frac{\lambda_j^H}{\lambda_j^L}\right)^{\sigma} = \left(\frac{p_j^L / \lambda_j^L}{p_j^H / \lambda_j^H}\right)^{\sigma}$$

In this case, the ad valorem barrier scales up the price of all goods proportionally. Relative demands for the goods depend only on their price relative to quality, and are independent of barriers. In the presence of the per unit cost, however, the ad valorem trade cost decreases the relative importance of the per unit trade cost in the final price of the good and therefore dampens its effect on the relative demand for the high quality good.

Freight rates may also be described in more general terms as combining both an ad-valorem and a per unit element. Freight rates may be positively related to goods' prices because of insurance charges, more costly handling requirements for higher quality goods, or the need to rely on more expensive transportation modes such as air shipping.[4] Also, if ocean liner cartels can succesfully exercise monopoly power in setting prices, their markups over marginal cost will be increasing in the goods price.[5] To reflect the possibility that freight rates are a function of the goods price, we write

(1.7) $$f_{ij} = p_j^{\beta} X_{ij}$$

where X is a vector of non-price factors such as distance, shipment quantity, or a commodity specific shifter that may raise the price. In this more general case, we describe the Alchian Allen effect in terms of the change in demand for quality caused by a change in X, the non-price portion of the freight charge.

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[4] Hummels (2001) examines transportation modal choice and shows that higher priced goods are more likely to be air-shipped.

[5] A monopoly shipper faces a transportation demand curve that is a function of import demand multiplied by the ad-valorem equivalent of the shipping charge. Higher priced goods have a lower ad-valorem equivalent so that transportation demand is less reponsive to changes in the transportation price. Thus, optimal markups are increasing in the goods' price.

(1.8) $$\frac{\partial\left(q_{ij}^{H}\big/q_{ij}^{L}\right)}{\partial X_{ij}}=\frac{\sigma}{t_{ij}}\left(\frac{\lambda_j^H}{\lambda_j^L}\right)^{\sigma}\left(\frac{p_j^L+f_{ij}/t_{ij}}{p_j^H+f_{ij}/t_{ij}}\right)^{\sigma-1}\frac{p_i^L p_j^H\left(\left(p_j^L\right)^{\beta-1}-\left(p_j^H\right)^{\beta-1}\right)}{\left(p_j^H+f_{ij}/t_{ij}\right)^2}$$

The sign and magnitude of Alchian Allen effects depend on β. For $\beta = 1$, we have the well-known case of iceberg transportation costs. Here, the freight rate is purely ad-valorem, and we can rewrite the price facing consumers as $p_{ij} = p_j(t_{ij} + X_{ij})$. Quantity shares for the high and low quality goods are given by equation (1.6), and no Alchian Allen effects exist. For $\beta < 1$, we have Alchian Allen effects, which grow stronger as $\beta \to 0$. At that point, the freight rate is per unit, and quantity shares are given by equation (1.3). The remaining case, $\beta > 1$ can be thought of as a reverse Alchian Allen effect – freight rates rise faster than goods prices so that an increase in the non-price portion of the freight rate (e.g. distance) actually raises the price of high relative to low quality goods.

To this point we have focused on the relative demand for quality assuming that the trade data allow us to identify high and low quality products as separate categories of goods. Suppose instead that the data are sufficiently aggregated that we observe a mix of qualities within a particular category of goods. Equation (1.8) cannot be directly applied because quantities of each quality type are not observed. In this case it is useful to describe the comparative statics in terms of the observed average price of shipments from a particular exporter.

(1.9) $$\overline{p}_{ij} = S_{ij}^{H} p_j^{H} + (1 - S_{ij}^{H}) p_j^{L}$$

S_{ij}^{H} denotes the share of high quality goods in the bundle for ij. The average category fob price is a weighted average of the fob prices for each quality. An increase in per unit freight rates increases the share of the high quality good, which increases the observed average price for a commodity. When looking over multiple importers, a particular exporter will charge destination-specific average prices because the shares of the high and low quality goods vary according to trade costs.

The sign of the Alchian Allen effect measured in average prices matches the sign of the effect measured in relative demand for qualities. However, the magnitude of the effect will always be smaller when measured in terms of average prices because the average price is bounded between the high and low prices. A comparison of the magnitudes can be seen in Figures 1 and 2. Figure 1 graphs the shares of high and low quality goods against X/t, for various values of β. We choose values such that quality adjusted fob prices are equal, or $p^{H} / \lambda^{H} = p^{L} / \lambda^{L}$. The range of X/t is given by the 90/10 percentile distribution of our data. Figure 2 graphs the average price of goods for the same X/t and β. A small change in the average prices can be a result of a large change in the ratio of the high to low quality goods.

III. Empirics

III.1 Data Description

Our data cover the bilateral trade of six importers (Argentina, Brazil, Chile, Paraguay, Uruguay, and the United States) with all exporters worldwide, measured at the 6 digit level of the Harmonized Classification System (5000+ categories) in 1994. We observe shipment values V, weight (WGT), the total freight bill paid (F), and the ad-valorem tariff rate (t). All included variables have true importer-exporter-commodity category variation. We use shipment weight as our measure of quantity, so the per unit freight rate is $f=F/WGT$ and prices are $p = V/WGT$. All data are expressed relative to commodity means, which subsumes differences in units across categories. That is, one can think of all categories in terms of a common unit (weight), or in terms of a category specific unit (e.g. number of shoes) multiplied by weight per category unit.

Data on V, WGT, and F are taken from national data sources for the importers. Bilateral tariff rates are taken from extracts of the UNCTAD TRAINS database. Per capita incomes are taken from the Summers and Heston Penn World Tables data.

We begin by describing the data and its variation in Table 1. For each observation (importer-exporter-commodity category), we describe prices relative to category means ($p_{ijk} / \overline{p}_k$), exporter-category means ($p_{ijk} / \overline{p}_{jk}$), and importer-category means ($p_{ijk} / \overline{p}_{ik}$). Then we report means and standard deviations of these statistics for all exporters, and exporters grouped into top 25th percentile and bottom 75th percentile by per capita income.[6] We repeat this exercise for per unit freight charges and for per unit freight charges/ad-valorem tariffs.

Table 1 shows that prices vary tremendously within a category (st.dev/mean = 5.1). Conditioning on an importer-category, prices vary a great deal over exporters (st.dev/mean = 2.26), and are higher for rich than for poor exporters. This is consistent with the results in Schott (2001) and Hummels and Klenow (2001) finding that within-

[6] There are more trade observations for richer countries and a greater range of variation in incomes at the high end. Cutting at the 25th percentile splits the number of observations in half, and provides a comparable range of income variation in both samples.

category price variation is positively correlated with exporter income. This data feature is consistent with richer exporters specializing in higher quality varieties and importers buying a bundle of qualities from different sources. Of most interest, conditioning on an exporter-category mean we see considerable variation in prices across importers (stdev/mean = .64). That is, exporters charge destinating varying prices for the same goods category. This is consistent with a model in which each exporter produces a number of varieties of differing quality within each 6-digit category. We observe (average) prices varying across destinations because the share of high and low quality goods in the bundle varies.[7]

Examining per unit freight charges, we see a pattern quite similar to prices. Freight rates and freight rates relative to tariffs vary considerably for a given category, somewhat less conditioning on an importer-category, and less still conditioning on an exporter-category. However, substantial variation across importers remains in freight charges (stdev/mean = .7) and freight relative to tariffs (stdev/mean = 1.19). Extensive variation of this sort is important if Alchian-Allen effects are to explain changes in the quality bundle across importers.

A final interesting fact from Table 1 is that freight charges are much higher for rich exporters. This seems somewhat counterintuitive, as rich exporters typically have better transportation infrastructure and enjoy scale benefits in shipping. The reason is that we are reporting freight charges per unit, rather than freight charges per value shipped. Rich exporters ship higher priced goods. If total freight charges are rising in value as in equation (1.7), we would expect that freight charges per unit would be higher

[7] An alternative explanation is that the observed price variation reflects destination-varying markups charged by exporting firms with market power. We address this alternative explanation in the final section.

for rich countries, while freight charges per value would be lower. This is exactly the case, suggesting that it will be important to account for simultaneity between prices and freight rates in estimating Alchian-Allen effects.

Empirical Specification

Our empirical examination of the Alchian Allen effect proceeds in two parts. Equation (1.8) shows that the existence and magnitude of the effect depends on the elasticity of freight rates with respect to price. To estimate this elasticity, write the per unit freight bill from exporter j to importer i in commodity k as a function of the goods' price, the distance shipped, total shipment quantity in a category[8], and a vector of commodity specific shifters α_k. This gives an estimating equation in logs

$$(1.10) \quad \ln f_{ijk} = \beta \ln(p_{ijk}) + \delta \ln(DIST_{ij}) + \omega \ln(Q_{ijk}) + \sum_k \alpha_k + e_{ijk}$$

Since the freight rate is defined in per quantity terms, inclusion of quantities on the right hand side reflects possible scale economies in shipping.

The second part of our empirical analysis consists of a direct test of the Alchian Allen effect. We model observed goods prices as a function of per unit freight rates, ad-valorem tariff rates, and the per capita incomes (y) of the exporter and importer.

$$(1.11) \quad \ln p_{ijk} = \gamma_1 \ln f_{ijk} + \gamma_2 \ln t_{ijk} + \gamma_3 \ln y_i + \gamma_4 \ln y_j$$

The comparative statics from the preceding section show that the quality shares (and therefore average prices) depend on the per unit freight and ad-valorem tarif rates. Summary statistics in Table 1, and recent papers by Schott (2001), and Hummels and

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[8] Our theory assumes that observed shipments are a mix of quality goods, but the observed quantities are the sum of quantities from all quality types.

Klenow (2001) show that prices are increasing in exporter income.[9] Finally, we have employed homothetic utility functions in our model for simplicity but we include importer income to incorporate the possibility that rich importers may have a taste for higher quality goods.

Section II considers relative demands for quality for a particular importer-exporter pair as the per unit freight rate rises. To implement this empirically, we have cross-sectional variation across importers i, exporters j and goods categories k that we might examine. The base specification in equation (1.11) employs variation over multiple ij pairs for many goods. We also examine variation across ij pairs for a given commodity k in order to take out commodity-specific variation in prices that may be unrelated to Alchian Allen effects.

$$(1.12) \quad \ln p_{ijk} = \gamma_1 \ln f_{ijk} + \gamma_2 \ln t_{ijk} + \gamma_3 \ln y_i + \gamma_4 \ln y_j + \sum_k \alpha_k + e_{ijk}$$

Finally, we examine variation across importers for a given exporter and commodity.

$$(1.13) \quad \ln p_{ijk} = \gamma_1 \ln f_{ijk} + \gamma_2 \ln t_{ijk} + \gamma_3 \ln y_i + \sum_{j,k} \alpha_{jk} + e_{ijk}$$

Specifications (1.11) and (1.12) control for exporter prices imperfectly by including exporter per capita income, whereas in (1.13), we completely control for variation across exporters in prices by taking out exporter-commodity means. Doing so potentially eliminates important sources of variation (across exporters, across commodities) in freight rates that could lead to Alchian Allen effects, but it also provides the experiment closest to the comparative statics performed in the theory section. That is, it holds

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[9] If production of quality is human or physical capital-intensive then countries well endowed with these factors have both higher income and a higher quality mix for goods in their trade bundle. Hummels and Klenow (2001) show more generally that a country with a relative technological advantage in producing higher quality goods will enjoy higher per capita income.

constant the supply side of the model (in prices and quantities of high and low quality goods), allowing only variation across importers due to freight rates. This issue is discussed further in Section IV.

There is a simultaneity problem between freight rates and prices in all equations, and, in equation (1.10), shipment quantities are endogenous to the freight rate. Happily our specification provides useful instruments. When estimating the effect of prices and quantities on freight rates, we instrument using tariffs and the incomes of exporters and importers. When estimating the effect of freight rates on prices, we instrument freight rates by the distance and quantity shipped. We also employ one year lagged values of prices as an instrument in this second equation.

Results

Table 2 reports estimates of equation (1.10) using OLS and IV estimators.[10] Two different samples are used. The first pools over all importer x exporter x commodity variation in our data. We find an elasticity of freight rates with respect to price around 0.6, well below the unitary elasticity implied by the iceberg assumption on shipping costs. Quantities enter negatively, suggesting a moderate scale effect in shipping. OLS and IV estimates are significantly different from each other in a statistical sense, but the economic effect of the magnitudes are quite similar. It should be noted that the reported R2 here are net of the fixed effects, and so these regressions do an excellent job of fitting the considerable variation we observe in freight rates.

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[10] First stage regressions for the IV estimators show that the instruments strongly co-vary with both price and quantity.

We also report this regression using a sample of US imports data measured at a much more disaggregated level (10 digit HS, or 17,000 goods). We further restrict the sample to include only those goods with count-based (rather than weight-based) quantity data available, and those cases where the data consist of only one shipment. More aggregated data and data consisting of multiple shipments provide a relationship between average freight rates and average prices (and quantities) within the ijk observation. By looking at single shipments of more disaggregated data we hope to identify a relationship between freight rates and prices for a homogeneous product. The third and fourth rows of table 2 report results. We find, in the IV regressions, a substantially weaker price effect and a substantially stronger quantity effect on freight rates. That is, for the more homogeneous records we find a case much closer to per unit than ad-valorem freight rates, and stronger scale economies in shipping.

Table 3 reports estimates of equations (1.11), (1.12), and (1.13), first using distance and shipment quantities as instruments for freight rates, and then using lagged values on the dependent variable as an instrument. We find strong support for the Alchian Allen hypothesis in all cases. Doubling freight rates increases average prices by 70 to 143 percent, depending on the estimation strategy. As predicted, ad-valorem freight rates significantly reduce average prices, which our theory suggests can only happen in the presence of significant per unit charges. Finally, the regressions that include exporter x commodity fixed effects are closest in spirit to our comparative statics, in that they allow only variation across importers to affect the measured elasticities. Compared to the other specifications, the magnitudes are quite similar suggesting that it is variation across importers that drives our results.

We provide several robustness checks. In Table 3 we pool over all commodity categories. We also estimate equation (1.13) separately for each 3-digit HS category, using shipment weight and distance as instruments and including exporter x 6-digit category fixed effects.[11] We plot the elasticity of prices with respect to freight rates on the vertical axis in Figure 3. Every 3-digit category shows significant Alchian-Allen effects. This makes it unlikely that something like an oligopoly pricing-to-market story[12] could explain our results.

Why does the magnitude of the effect vary over categories? Recall from equation (1.4) that our model predicts Alchian-Allen magnitudes will differ across commodities depending on the range of prices (qualities) available from the exporter. Simply, if the exporter produces only a single quality then it is not possible for the quality mix to change over importers in relation to trade costs.

Since we are interpreting our data in terms of average prices, we cannot directly observe the full range of price variation available from an exporter. However, average prices are bounded by the true variation which means we can use the variation in average prices to determine a minimum possible range: the lowest (highest) price available from the exporter must be at least as low (high) as the lowest (highest) observed average price. We calculate the distribution of prices relative to exporter-6-digit category means for each 3-digit category, and represent price dispersion using the $90^{th}/10^{th}$ percentile split prices on the horizontal axis in Figure 3. Alchian-Allen effects are strongest for those commodities in which we observe the widest variation in prices.

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[11] We pool over 3-digit categories because at 4-,5-,and 6-digit levels we have sufficiently few observations that our estimates begin to lose precision. However, the results are very similar to the 3-digit results.
[12] See Goldberg and Knetter (1997) for a survey of pricing to market.

Finally, our identification strategy relies on the assumption that variation in average prices within a category reflect changes in the composition of a quality bundle. This requires that the 6-digit detail groups together goods that are similar, but not homogeneous with respect to quality. But even at this level it may be that the categories sweep in a mix of goods sufficiently dissimilar that it would be inappropriate to apply our model. To check this, we use the 10-digit Harmonized System data employed by the US Census Bureau to calculate how many different 10 digit product lines appear in each 6 digit category. Call this N_k. We then pool 6-digit categories by N_k and re-estimate equation (1.13). We find that the magnitude of the AA effect is weaker for 6-digit categories with higher N_k, but the effect is positive and significant regardless of how much category heterogeneity exists below the 6-digit level.

IV. Alternative explanations.

We have considered an endowment economy with perfectly competitive firms in deriving Alchian Allen effects in Section II and estimating them in Section III. In this section, we consider two alternative explanations for our results. First we examine effects on average prices when the supply side of the model is also allowed to respond. Second, we relax the assumption of perfect competition, and show that the presence of per unit costs will cause monopolistically competitive firms to charge destination-varying markups over marginal cost.

Supply Responses

Consider first what might be called "traditional" transport cost incidence. The notion that higher shipping costs affect fob prices is not new, but the typical formulation posits a negative relationship. Suppose we have a competitive firms with an upward sloping supply for a homogeneous good. Now, increase the freight charge this exporter pays in shipping to all destinations (or equivalently, compare one country more distant from world markets than a second). Increasing the freight charge lowers the fob price that firms can charge. In the limiting case of a small country facing fixed world prices, the fob price decline should exactly offset the freight increase.

The distinction between traditional transport cost incidence and the Alchian Allen effect is that in the former case shipping costs change the common fob prices that firms charge to all destinations. This variation might be picked up by our estimates that pool over multiple exporters, equations (1.11) and (1.12). However, these supply responses do not affect our estimates of equation (1.13); in that instance, price changes common to all importers for a given exporter-commodity are already removed by the fixed effects. Since the estimated effects are quite similar across those three specifications it follows that traditional incidence is relatively unimportant.

Destination Varying Markups

We have previously assumed perfectly competitive firms so that we could treat the price of any one good as equal to the marginal cost of production, and invariant across destinations. Assuming this, any variation in average prices across importers for a given exporter-commodity must be the result of changing shares of high and low quality goods.

If we have instead monopolistically competitive firms, fob prices now include both marginal cost of production and a markup. A familiar result from the trade literature holds that fob prices are invariant to destination because the markup over marginal cost is constant. That result is contingent on all trade costs being ad-valorem. A per unit charge alters this formulation and optimal markups will vary over destinations.

Suppose that preferences are CES, but each country produces only a single quality in a monopolistically competitive sector. Consumer prices include both a per unit charge *f*, and an ad-valorem cost *t*. The profit maximization problem implies a (fob) pricing rule of

(1.14) $$\frac{p_{ij}}{MC_j^H} = \frac{f_{ij}}{t_{ij}} \frac{1}{(\sigma - 1)MC_j} + \frac{\sigma}{\sigma - 1}.$$

The pricing rule contains the markup over marginal costs, $\sigma/(\sigma-1)$, that is familiar in the literature, plus an additional term that is destination specific. Prices are increasing in the per unit freight charge and decreasing in the ad-valorem tariff. In short, pricing-to-market driven by per unit costs would give precisely the same *sign* pattern of price variation we have observed in our regressions. However, the variation in markups is much too small to explain the magnitudes we observe. Using the f/t variation we observe in our data, and a value of $\sigma = 5$ (Hummels, 2001), the elasticity of price with respect to the freight rate would be on the order of 0.007. This compares unfavorably to estimated elasticities of 0.7 – 1.4 shown in Table 3.

We can also extend our analysis of Alchian Allen effects on the quality mix within this model. Suppose preferences are the same as in Section II. High and low quality goods are respectively produced by two sectors of monopolistically competitive firms with marginal costs of MC^H and MC^L. Given fob prices above, the price facing the consumer is now

$$(1.15) \quad p_{ij}^H t_{ij} + f_{ij} = \frac{\sigma}{\sigma - 1}\left(f_{ij} + MC_j^H t_{ij}\right)$$

Relative demands for quality are

$$(1.16) \quad \frac{q_j^H}{q_j^H} = \left(\frac{MC_j^L + f_{ij} / t_{ij}}{MC_j^H + f_{ij} / t_{ij}}\right)^{\sigma} \left(\frac{\lambda_j^H}{\lambda_j^L}\right)^{\sigma}$$

Compare this to the relative demands for quality described in the perfectly competitive setup in Section II, equation (1.3). Since prices under perfect competition are given by the marginal costs of production, relative demands are exactly the same in the perfect competition and monopolistic competition cases. That is, while the markups raise the fob price of high and low quality goods relative to the perfect competition case, the relative price faced by the consumers remains the same. All of our comparative statics on relative demands go through as before. However, average prices observed in our trade data move for two reasons. Markups on both goods, as well as Alchian Allen effects increasing the share of the high price good, are increasing in f and decreasing in t.

V. Conclusions

We formalize the Alchian Allen "shipping the good apples out" hypothesis, showing that the shares of high relative to low quality goods in an import bundle will be increasing in the per unit freight rate and decreasing in ad-valorem costs. We test this hypothesis by relating average prices charged by an exporter in a particular commodity to freight and tariffs. Fob prices vary considerably over importers and provide strong support for the theory: doubling freight rates increases fob prices by 70 – 143 percent; doubling the ad-valorem tariff rate decreases prices by a factor of 3-4.

Critical to this demonstration is the idea that shipping costs are applied on a per unit rather than ad-valorem basis. Freight rates do not move relative demands for quality if they are linear in the value of goods being shipped. This is, of course, the standard assumption on international transportation costs. We show directly, by estimating the shape of the shipping cost function, and indirectly, by finding large Alchian Allen effects, that the iceberg assumption is neither correct nor innocuous.

We provide a complementary interpretation of our results in terms of pricing-to-market by monopolistically competitive firms. With ad-valorem trade costs, these firms charge the same fob price to all destinations. In the presence of per unit charges, markups vary positively with freight rates and negatively with tariff rates. However, the predicted markup variation is too small to explain the observed movements in average prices.

Finally, the price effects we observe are quite large and the implied changes in quality shares are even larger. This suggests the likelihood that Alchian Allen effects could lead to a general equilibrium response in the supply of quality. We leave to future work this question: could the very high quality of Japanese manufactures be partly the result of its remote location?

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Table 1 – Summary Statistics

PRICES	Variation relative to	Exporter-category mean	Importer-category mean	Category mean
All exporters	st.dev.	0.64	2.26	5.10
	mean	1	1	1
Top 25th p'tile by income	st.dev.	0.67	2.83	6.73
	mean	1	1.15	1.31
Bottom 75th p'tile by income	st.dev.	0.61	1.34	2.07
	mean	1	0.8	0.65

FREIGHT CHARGE	Variation relative to	Exporter-category mean	Importer-category mean	Category mean
All exporters	st.dev.	0.70	1.95	3.67
	mean	1	1	1
Top 25th p'tile by income	st.dev.	0.73	2.34	4.64
	mean	1	1.11	1.18
Bottom 75th p'tile by income	st.dev.	0.68	1.38	2.11
	mean	1	0.88	0.80

FREIGHT CHARGE/TARIFF	Variation relative to	Exporter-category mean	Importer-category mean	Category mean
All exporters	st.dev.	1.19	1.72	3.61
	mean	1	1	1
Top 25th p'tile by income	st.dev.	1.20	1.95	4.40
	mean	1	1.06	1.12
Bottom 75th p'tile by income	st.dev.	1.18	1.41	2.38
	mean	1	0.93	0.86

Table 2. Freight Rates.

Dep var: Ln(freight rate)	Variables			R^2	Observations
	Price	Distance	Quantity		
(1) OLS, all countries	0.64 (0.0012)	0.26 (0.0019)	-0.12 (0.0005)	0.64	275398
(2) IV*, all countries	0.61 (0.0048)	0.25 (0.0020)	-0.18 (0.0022)	0.63	254031
(3) OLS, restricted US sample	0.716 (0.0017)	0.114 (0.0017)	-0.219 (0.0024)	0.83	299409
(4) IV* restricted US sample	0.125 (0.0138)	0.221 (0.0050)	-0.480 (0.0142)	0.69	277756

All variables are in log levels and mean differenced by commodity;
* - in these regressions price and quantity are instrumented by tariffs, and exporter and importer GDP per capita.

Table 3. Alchian Allen Effects.

Dep var: ln(shipment price)	Variables				R^2	Obs.
	Freight	Tariff	y_i/L_i	y_j/L_j		
Freight rate is instrumented by shipment weight and distance.						
(1) IV, pooled	0.95 (.0020)	-1.18 (.0372)	0.46 (.0048)	0.18 (.0032)	0.70	254031
(2) IV, commodity differenced	0.798 (.0023)	-1.56 (.0368)	0.46 (.0044)	0.20 (.0029)	0.60	254031
(3) IV, commodity and exporter differenced	0.84 (.0026)	-1.46 (.0289)	0.53 (.0036)	--	0.53	275398
Freight rate is instrumented with lagged values of dependent variable.						
(4) IV, pooled	1.35 (.0038)	-3.18 (.0726)	0.27 (.0091)	0.01 (.0063)	0.60	91989
(5) IV, commodity differenced	1.33 (.0072)	-2.56 (.0787)	0.34 (.0092)	-0.03 (.0067)	0.34	91989
(6) IV, commodity and exporter differenced	1.41 (.0144)	-2.28 (.0689)	0.62 (.0087)	--		100118