

Shipping the Good Apples Out? An Empirical Confirmation of the Alchian-Allen Conjecture

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October 2003

Abstract: Alchian and Allen (1964) show that a per unit transactions cost lowers the relative price of, and raises the relative demand for, high quality goods. We extend their theory, deriving a relationship between per unit and ad-valorem trade costs and the quality composition of trade. Detailed international trade data for many importers and exporters are used to test these predictions. Within a narrowly defined commodity classification, exporters charge destination-varying prices that co-vary positively with shipping costs and negatively with tariffs. These results provide a clear rejection of the iceberg assumption on transportation costs and a strong confirmation of the classical Alchian-Allen hypothesis. We show that these results cannot be explained by monopoly pricing-to-market behavior.

Acknowledgements: We thank two anonymous referees, Fernando Alvarez, Jack Barron, Christian Dahl, Peter Klenow, Dan Kovenock, Kala Krishna, Peter Schott, John Umbeck, and seminar participants at the NBER Summer Institute for helpful comments and discussions. Thanks also to Purdue CIBER for funding.

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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 This point was originally made by Alchian and Allen (1964), and was described by them more colorfully as “shipping the good apples out”. That is, 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 extends the Alchian-Allen conjecture and confirms it using extensive international trade data. In addition, we provide strong evidence against a widely used assumption in the trade literature: that transportation costs are of the “iceberg” form, proportional to goods prices.

In the traditional formulation, the Alchian-Allen hypothesis examines the relative quality of goods shipped to distant versus local markets within a country. Trade flows within a country are largely unobserved, making this a difficult hypothesis to formally test in the domestic setting. The observability of trade flows is not a problem in an international context but one must worry about variation in other trade costs such as tariffs. We extend the theory on Alchian-Allen effects to show that they depend on the relative strength of per unit and ad-valorem costs. Transportation costs raise the relative demand for high quality goods, while tariffs lower it.

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 measured at the 6-digit level of the Harmonized System (more than five thousand goods). The data include prices, quantities, shipping costs, and ad-valorem tariffs specific to each bilateral flow. An important characteristic of these data is that, conditional on the exporter and commodity, prices vary considerably over importers. That is, exporters appear to charge destination-varying f.o.b.

(“free on board”, exclusive of shipping costs) prices for the same good. To interpret this, we assume that exporters produce goods of varying quality and price within a 6-digit commodity classification. Observed prices in the trade data are then share-weighted averages of prices within each 6-digit category, with observed price differences reflecting differences in the quality mix across destinations.

Our estimation proceeds in two parts. First, we estimate a transportation cost function and show that these costs more closely resemble per unit, rather than per value, charges. This property is necessary for transport costs to affect the quality composition of trade. Conditioning on an exporter and commodity, we then relate variation across destinations in the (f.o.b.) prices of traded goods to the magnitude of shipping costs and tariffs. We find that doubling shipping costs leads to an 80-141% increase in average f.o.b. prices, while doubling tariffs reduces average f.o.b. prices by 146-256%. This sign pattern is observed for all commodity groups in the data, with the magnitude of the effect varying across goods in a manner suggested by the theory.

We contribute to three distinct literatures. The first literature concerns trade in quality and how it is affected by trade costs. While there is a large theoretical literature on trade in quality, empirical work has until recently been scarce.¹ Similarly, the theoretical literature on Alchian-Allen effects has examined in some detail the conditions under which relative demands for quality depend on per unit transportation costs, but no previous work has examined these hypotheses empirically.²

There is a large literature linking international trade quotas to quality change. Under the assumption of perfect competition, Falvey (1979) shows that quotas alter relative demands for

¹ Two recent exceptions are Schott (2001) and Hummels and Klenow (2001).

² Theoretical examinations of the Alchian-Allen conjecture include Gould and Segall (1969), Borchering and Silberberg (1978), and Umbeck (1980).

quality in a manner very similar to Alchian-Allen effects.³ A number of authors have examined this question empirically, with most finding increased quality in the years immediately after the quota was imposed.⁴ The difference with our work is two-fold. The empirical work on quotas focuses on time series changes that result from imposing quotas, and therefore includes changes in the decision to produce quality. We employ cross-sections, holding the supply of quality in a particular exporter as fixed and examining how barriers affect the quality mix shipped across destinations. Note also that quota restrictions are relevant for a small number of goods, a set that should dwindle in importance as WTO rules shift member nations away from quantitative restrictions. In contrast, transport costs and tariffs are ubiquitous and bind on all trade flows regardless of size, making Alchian-Allen effects an arguably more important force affecting the quality mix of trade.

The second contribution is to several literatures that introduce trade costs into models of trade, especially those that employ a monopolistically competitive market structure.⁵ Nearly all such models adopt the iceberg assumption on transportation costs, which affects model outcomes in four ways. First, applying a common iceberg melt factor to all goods preserves relative prices, which means relative demands are unaffected. Second, the iceberg melt does not distort the pricing rule so that firms charge the same (f.o.b.) prices in all markets. Third, the production of transportation can be safely ignored because the iceberg melt is equivalent to assuming that transportation technology is identical to the technology for producing goods. Fourth, empirical analysis of these models as in the gravity equation literature can employ trade values, rather than

³ This result depends on market structure, and models with imperfect competition and strategic interactions can yield opposite predictions. See Krishna (1990) for a survey of models with imperfect competition and Herguera et al (2000) for references to sequential choice models.

⁴ However, the quality effect is not persistent. See Aw and Roberts (1986), Feenstra (1988), and Boorstein and Feenstra (1991).

⁵ A short list: the literatures on trade and geography, multinationals in trade, and measurement of home bias in trade.

prices and quantities separately, and relate them in a simple log-linear way to trade costs. We show that the iceberg assumption is neither correct nor innocuous: transport costs and tariffs do alter relative prices in ways that significantly affect relative demand. This suggests the need to revisit theoretical and empirical findings that turn on the iceberg assumption.

Finally, our work relates to a literature that examines price variation across destinations. One part of this literature suggests that price variation across destinations is due not to quality variation, but to pricing-to-market (PTM) behavior by monopolists. In these models, monopolists absorb some portion of ad-valorem cost shocks due to movements in tariffs or exchange rates. This means that (f.o.b.) prices vary across destinations, and negatively co-vary with ad-valorem cost shifters. In order to rule out PTM behavior as an explanation for our results, we extend theoretical models of PTM to include per unit trade costs. We show that PTM alone cannot explain the magnitude of our price elasticity with respect to tariffs, or the sign of our price elasticity with respect to transportation costs. This is not to say that PTM is unimportant, only that it must be complemented by Alchian-Allen effects to explain the ubiquity, sign, and extent of price variation across markets.

A second part of this literature examines the price of re-exported goods, and the role of entrepots such as Hong Kong in adding value to and/or sorting re-exported goods by quality.⁶ As in our model, export prices leaving an entrepot may vary because of quality composition, but these papers are focused more on the sorting function itself. Distance is included as a control for Alchian-Allen effects, though authors find that distance actually decreases prices. There are three potential reasons for the difference between our results and this literature. One, the previous literature focuses on re-exports, especially those through Hong Kong, and there may be

⁶ See Hanson and Feenstra (2001) and Young (1999).

something special about these cases. We have much broader exporter coverage, and exclude re-exports from our data to focus on Alchian-Allen effects. Two, these studies omit tariffs, which we show theoretically and empirically to be important for identifying changes in the quality mix. Three, distance alone may be an imperfect proxy for transportation costs, and our instrumental variables approach yields a better picture of the true variation in these costs.

Section II extends the Alchian-Allen literature to include tariffs and the empirically relevant case of transportation costs that are a mix of per unit and ad-valorem components. Section III tests these conjectures. Section IV extends the pricing-to-market literature to include per unit transport costs and shows that PTM alone cannot explain our results. Section V concludes.

II. Relative Demands for Quality

This section examines relative demands for quality in response to changes in ad-valorem and per unit trade costs. We suppose that an exporting country j supplies goods of high (H) and low (L) quality, each from a competitive sector.⁷ In order to focus on the mix of quality shipped to different destinations, we take supply as fixed. Consider a simple Hicksian compensated demand function⁸ for importer i .

$$(1) \quad q_{ijg} = h(p_{ijH}^*, p_{ijL}^*, p_{iC}), \quad g = H, L.$$

Demand depends on the price of the high and low quality goods and p_{iC} , the price of a Hicksian composite commodity that includes all other goods.

⁷ Production may yield joint output of high and low quality types (apples), or we may have two types of firms who differ in their cost of producing quality, leading them to specialize in high and low quality goods respectively.

⁸ The Alchian-Allen conjecture is primarily a statement about substitution effects. It is standard in this literature to ignore income effects in order to isolate changes in relative quantities due to changes in relative prices. This can be done using Hicksian demands, or by assuming a specific homothetic structure for utility. Either way, it is important to note that income effects of the proper sign and size could undo these theoretical propositions, making the ultimate relationships an empirical matter.

Suppressing quality subscripts, the price of the good facing the consumer depends on the f.o.b. 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} .

$$(2) \quad p_{ij}^* = p_j t_{ij} + f_{ij}$$

With competitive firms, the firm's f.o.b. price is independent of the final destination. In section IV we compare our results to the pricing-to-market behavior of monopolistic firms.

In this model, the Alchian Allen hypothesis can be seen by examining the effect of trade costs on the demand for high relative to low quality goods originating in j , q_{ijH}/q_{ijL} . A change in the per unit charge f_{ij} results in⁹

$$(3) \quad \frac{\partial \left(\frac{q_{ijH}}{q_{ijL}} \right)}{\partial f_{ij}} = \frac{q_{ijH}}{q_{ijL}} \left[(\varepsilon_{HH} - \varepsilon_{LH}) \left(\frac{1}{p_{ijH}^*} - \frac{1}{p_{ijL}^*} \right) + (\varepsilon_{LC} - \varepsilon_{HC}) \frac{1}{p_{ijL}^*} \right]$$

The first two terms in this derivative constitute the direct substitution effect, where ε_{HH} is the own-price elasticity of demand for the high quality good, and ε_{LH} is the cross-price elasticity of the low quality good with respect to the high quality good. The direct substitution effect is positive so long as the goods are substitutes ($\varepsilon_{LH} > 0$), and prices are increasing in quality, $p_{jH} > p_{jL}$. The last part of the expression is the indirect substitution effect caused by interactions with the composite good. Its sign is given by the difference between the cross price elasticities of the low ε_{LC} and high ε_{HC} quality goods with respect to the composite good. The theoretical literature on Alchian-Allen effects assumes this term is approximately equal to zero, so that the sign on the overall derivative is positive. This would be the case if both cross-price

⁹ Our derivation procedure is similar to Borchering, Silberberg (1978). Appendix available on request.

elasticities are zero, for example, if utility were Cobb Douglas in the composite good.¹⁰ Or, it might be that the cross-price terms were both positive but of equal magnitude, for example, if utility were weakly separable in the composite commodity.¹¹

The strength of the Alchian-Allen effect depends positively on the difference in prices for high and low quality goods. The intuition is that the impact of a per unit cost on relative prices (inclusive of the per unit cost) is increasing in the price difference.¹² We use this fact to explore cross-industry variation in Alchian-Allen effects in the empirical section.

The previous literature ignores tariffs, but their presence qualifies Alchian-Allen effects in an interesting way. Assuming away interactions with the composite good, a change in the ad-valorem tariff has the opposite effect of transportation costs: the relative demand for the higher priced good is decreasing in the ad valorem part of the trade costs.

$$(4) \quad \frac{\partial \left(\frac{q_{ijH}}{q_{ijL}} \right)}{\partial t_{ij}} = \frac{q_{ijH}}{q_{ijL}} \left[(\varepsilon_{HH} - \varepsilon_{LH}) \left(\frac{p_{jH}}{p_{ijH}^*} - \frac{p_{jL}}{p_{ijL}^*} \right) + (\varepsilon_{LC} - \varepsilon_{HC}) \frac{p_{jL}}{p_{ijL}^*} \right]$$

Again, the first term is negative and the last term approximately zero by assumption. The middle term is positive; it is the ratio of origin prices to destination prices inclusive of trade costs for the high quality good less this same ratio for the low quality good. Were barriers purely ad-valorem, $f_{ij} = 0$, then the ratio would be $1/t_{ij}$ for both qualities. With per unit barriers, origin prices are closer to destination prices for the high quality good.

¹⁰ This assumption is problematic when we confront the existence of multiple exporters in our data. It would be odd to assume that consumers expended a constant share of income on Japanese motorcycles of high and low quality, and a separate income share on a composite good that included German motorcycles.

¹¹ That is, for a US consumer, the cross-price elasticity of a large-engine Japanese motorcycle with respect to all other goods in the consumption bundle (including German motorcycles) is roughly equal to the cross-price elasticity of a small-engine Japanese motorcycle with respect to all other goods in the bundle.

¹² For example, start with a relative price of 5/1. Adding a per unit cost of 1 changes the relative price to 3. Adding the same per unit cost to a relative price of 1.2 yields a small change in relative prices to 1.1.

Put another way, the direct substitution effect in (4) is negative because a tariff increase reduces the importance of the per unit transport cost. Consider the relative prices of the two qualities at destination i .

$$(5) \quad \frac{p_{ijH}^*}{p_{ijL}^*} = \frac{t_{ij}p_{jH} + f_{ij}}{t_{ij}p_{jL} + f_{ij}} = \frac{p_{jH} + f_{ij}/t_{ij}}{p_{jL} + f_{ij}/t_{ij}}$$

If $f_{ij} = 0$, the tariff scales up the price of all goods proportionally. If $f_{ij} > 0$, the impact of transport costs on relative prices depends on their magnitude relative to the tariff. When the ad-valorem tariff rises, it dampens the effect of the per unit transport cost on the relative demand for the high quality good.

More generally, transport costs may combine both an ad-valorem and a per unit element. Transport costs 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. Also, if ocean liner cartels can successfully exercise monopoly power in setting prices, their markups over marginal cost will be increasing in the goods price.¹³ To reflect the possibility that freight rates vary across quality types as a function of the goods price, we write

$$(6) \quad f_{ij} = p_j^\beta X_{ij}$$

where β is the elasticity of freight costs with respect to prices, and X_{ij} is a function of non-price factors such as distance, shipment quantity, or a commodity specific shifter that may alter shipment costs. In this more general case, we describe the Alchian-Allen effect in terms of the

¹³ 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 responsive to changes in the transportation price. Thus, optimal markups are increasing in the goods' price.

change in demand for quality caused by a change in X_{ij} , the non-price portion of the freight charge.

$$(7) \quad \frac{\partial \left(\frac{q_{ijH}}{q_{ijL}} \right)}{\partial X_{ij}} = \frac{q_{ijH}}{q_{ijL}} \left[(\varepsilon_{HH} - \varepsilon_{LH}) \left(\frac{(p_{jH})^\beta}{p_{ijH}^*} - \frac{(p_{jL})^\beta}{p_{ijL}^*} \right) + (\varepsilon_{LC} - \varepsilon_{HC}) \frac{(p_{jL})^\beta}{p_{ijL}^*} \right]$$

The sign and magnitude of Alchian Allen effects depend on β . $\beta = 1$ corresponds to the oft-assumed “iceberg” case in which transport costs are purely ad-valorem. We can then rewrite the price facing consumers as

$$(8) \quad p_{ij} = p_j(t_{ij} + X_{ij}) \quad \text{or} \quad \frac{p_j}{p_{ij}} = \frac{1}{t_{ij} + X_{ij}}$$

Using (8) in (7), we find the derivative equals zero, or no Alchian-Allen effect. For $\beta < 1$, Alchian-Allen effects exist, and grow stronger as β decreases. At $\beta = 0$, the freight rate is per unit, and equation (7) reduces to (3). The remaining case, $\beta > 1$ can be thought of as a reverse Alchian-Allen effect; transport costs rise faster than goods prices so that an increase in the non-price portion of the transport cost (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 (7) 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.

$$(9) \quad \bar{p}_{ij} = S_{ij}^H p_j^H + (1 - S_{ij}^H) p_j^L$$

S_{ij}^H denotes the share of high quality goods in the bundle for ij . The average category f.o.b. price is a weighted average of the f.o.b. prices for each quality. The sign of the Alchian Allen effect measured in average prices matches the sign of the effect measured in relative demand for qualities. An increase in per unit transport costs (or a decrease in ad-valorem tariffs) increases the share of the high quality good. This increases the observed average price for a category. When looking over multiple importers, a particular exporter will vary the shares of high and low quality goods across destinations, leading to variation in average prices over destinations.

III. Empirics

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. Denote a 6-digit commodity category by k . The national trade data for each importer reports the total freight bill paid (F_{ijk}), shipment values measured f.o.b., or net of the freight bill ($V_{ijk} - F_{ijk}$), and weight (WGT_{ijk}). We calculate bilateral ad-valorem tariffs (t_{ijk}) from the UNCTAD TRAINS database.¹⁴ We use shipment weight as our measure of quantity, so the per unit freight rate is $f_{ijk} = F_{ijk} / WGT_{ijk}$ and f.o.b. prices are $p_{ijk} = (V_{ijk} - F_{ijk}) / WGT_{ijk}$. The use of weight, instead of count, data as a quantity measure is not problematic. In our empirical analysis, we will express data relative to commodity k means, which subsumes differences in units across categories. That is, one can

¹⁴ To get bilateral variation, we employ a special extract of the TRAINS data constructed by Jon Haveman, called “The Ultimate Trade Barrier Catalog”, www.eiit.org.

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.

Given our modeling framework, we treat prices observed in the trade data as weighted averages of prices within each category k , as in equation (9). Identifying Alchian-Allen effects then requires that prices and trade costs vary substantially across destinations for a given 6-digit k . To see this variation, take each observation ijk (importer-exporter-commodity category), express the price relative to category k means (p_{ijk} / \bar{p}_k) , and calculate the standard deviation of that variable (the mean of the new variable is one by construction). In our data, the standard deviation of (p_{ijk} / \bar{p}_k) is 5.10. This reveals substantial variation in prices across ij pairs for a given product category k . If we express the price relative to jk means (p_{ijk} / \bar{p}_{jk}) , we find a standard deviation of 0.64. That is, conditioning on an exporter-commodity and examining variation across destinations leaves us with substantial variation in prices, albeit less variation than when we also exploit the cross-exporter dimension. We repeat this exercise for trade costs, measured as freight charges divided by ad-valorem tariffs (f_{ijk} / t_{ijk}) . When expressed relative to commodity k means, the standard deviation is 3.61. When expressed relative to exporter j - commodity k means, the standard deviation is 1.19. This gives us substantial trade cost variation with which to try and explain price variation.

Empirical Specification

Our empirical examination of the Alchian-Allen effect proceeds in two parts. Equation (7) 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, and total

shipment quantity in a category k . Costs may be commodity specific because of unobserved differences in bulk or handling requirements, so we difference the data relative to commodity k means. This gives an estimating equation in logs

$$(10) \quad \ln f_{ijk} - \overline{\ln f_k} = a + \beta (\ln p_{ijk} - \overline{\ln p_k}) + \omega (\ln WGT_{ijk} - \overline{\ln WGT_k}) \\ + \delta (\ln DIST_{ij} - \overline{\ln DIST_k}) + (\varepsilon_{ijk} - \overline{\varepsilon_k})$$

Since the freight rate is defined in per quantity terms, inclusion of shipment quantities on the right hand side reflects the possibility that costs per unit are rising or falling in shipment size.¹⁵

The error term reflects measurement error, as well as unobserved cost shifters such as regulatory or technological heterogeneity specific to shipments ijk .

The second part of our empirical analysis consists of a direct test of the Alchian-Allen effect. The comparative statics from the preceding section show that quality shares (and therefore average prices) depend on per unit freight costs and ad-valorem tariffs. Recent papers by Schott (2001), and Hummels and Klenow (2001) show that export prices are increasing in exporter income, y_j .¹⁶ Finally, we include importer income, y_i , to incorporate the possibility of non-homothetic demands for quality.¹⁷

¹⁵ There are three possible explanations for costs to vary over shipment sizes. One, if shipping requires technology that is specific to individual products (e.g. refrigerated cargoes, cranes for containerized goods, roll-on/roll-off vehicles for cars), increased scale allows the adoption of shipping technology better matched to the individual product. Two, the cost of providing shipping may be lower for larger cargoes because they require less packaging and handling per unit. This is most clear for shipments small enough that they must first be aggregated with other shipments into standard-sized shipping containers. Three, if the shipping industry is not competitive, shipping firms with some monopoly power could be engaging in second-degree price discrimination

¹⁶ 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.

¹⁷ Per capita income variables are taken from the Penn World Tables.

We use two specifications that differ only in the manner that we mean-difference the data. In the first specification, we calculate variable means relative to a 6-digit commodity k , and express all variables relative to these means.

$$(11) \quad \begin{aligned} (\ln p_{ijk} - \overline{\ln p_k}) = & \phi (\ln f_{ijk} - \overline{\ln f_k}) + \tau (\ln t_{ijk} - \overline{\ln t_k}) + \gamma_1 (\ln y_i - \overline{\ln y_k}) \\ & + \gamma_2 (\ln y_j - \overline{\ln y_k}) + (e_{ijk} - \overline{e_k}) \end{aligned}$$

This leaves us with variation across all ij pairs for a given commodity k . Differencing in this way removes commodity-specific variation in prices that may be unrelated to Alchian-Allen effects (e.g. a low quality car might be much more expensive than a high quality stereo system). Recalling equations (3) and (4), clearly signing the Alchian-Allen derivatives requires that the goods are substitutes ($\varepsilon_{LH} > 0$) and have similar cross-price elasticities with respect to the composite commodity $\varepsilon_{LC} \approx \varepsilon_{HC}$. These conditions are most safely met by considering within-commodity variation. Note that our theory described only a single exporter. Exploiting variation across importers and exporters for a given commodity is legitimate as long as supply conditions (the level and distribution of prices within commodity k) are similar across exporters.¹⁸ Finally, the error terms capture measurement error in prices, which is common in highly disaggregated trade data of this sort.

Second, we difference all variables with respect to their means over a given exporter j and 6-digit commodity k .

$$(12) \quad (\ln p_{ijk} - \overline{\ln p_{jk}}) = \phi (\ln f_{ijk} - \overline{\ln f_{jk}}) + \tau (\ln t_{ijk} - \overline{\ln t_{jk}}) + \gamma_1 (\ln y_i - \overline{\ln y_{jk}}) + (e_{ijk} - \overline{e_{jk}})$$

¹⁸ We show above that our price data exhibit more variation when looking across all ij pairs than when we condition on an exporter j and look only at variation across destinations. This could be either because prices within a category k vary across exporters, or because the greater variation in trade costs across ij pairs leads to greater variation in quality shares and therefore greater variation in average prices.

The income per capita of the exporter has been dropped as it is now a constant. This specification conditions on an exporter and commodity in order to examine variation across destinations i .¹⁹ Doing so eliminates potentially important sources of cross-exporter variation in trade costs that help identify the Alchian-Allen effects, but it also provides the experiment closest to the comparative statics performed in the theory section. That is, it holds constant the supply side of the model (the producer prices for the high and low quality goods), allowing variation in prices across importers to arise purely due to changes in the quality mix.

Examining equations (10), (11), and (12), we have the freight bill as a function of prices, and average prices as a function of the freight bill. In (10), freight costs are increasing in goods prices (due to insurance or increased handling requirements), but the average observed price is also increasing in the freight bill (because of the Alchian-Allen effects on the quality mix). To handle simultaneity in (10), we employ two strategies. First, we instrument for prices using the exogenous variables in equation (11): tariffs, and incomes for the importer and exporter. Second, we employ a special sub-sample of the data for which changes in the quality mix should be less important. To explain, the US imports data are also available at a much more disaggregated level (10 digit HS, or 17,000 goods) than the rest of the data. Also, it is possible to identify cases where quantities are reported on a count basis, rather than weight, and where an ijk record consists of only a single shipment (rather than the hundreds of shipments that comprise a typical ijk record). By restricting the sample in this manner, we hope to identify records with considerably less within-category heterogeneity in prices, reducing the simultaneity of freight costs on prices through the quality mix.

¹⁹ Knetter (1989,1993) expresses prices relative to exporter-commodity means and examines variation across destinations.

In equations (11) and (12), prices are predicted to be increasing in the freight bill due to Alchian-Allen effects, but the freight bill may be rising in prices because more expensive goods pay higher insurance fees and have more onerous handling requirements. We use two strategies. First, we instrument for the freight bill using the exogenous variables in equation (10), the distance shipped and the shipment weight.²⁰ This allows us to relate variation in prices to variation in the non-price portion of the freight bill. We also employ one year lagged values of prices as an instrument in this second equation.

Results

Table 1 reports estimates of equation (10) using OLS and IV estimators.²¹ The first two rows report results using the full sample of all importers and exporters. 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, meaning that the cost per unit is decreasing in total units shipped. OLS and IV estimates are significantly different from each other in a statistical sense, but the economic significance of the magnitudes is quite similar.

The third and fourth rows of table 1 report results using the sub-sample of US data that removes sources of heterogeneity in the product mix. We find, in the IV regressions, a substantially weaker price effect and a substantially stronger quantity effect on freight costs. That is, when we examine more homogeneous shipments in order to remove simultaneity between freight costs and goods prices, the elasticity of freight costs with respect to price drops.

²⁰ We also used exporter and importer size, measured as total GDP, as instruments. These variables are highly correlated with shipment sizes. Results are similar.

²¹ First stage regressions for the IV estimators show that the instruments strongly co-vary with both price and quantity.

This suggests that the shipping technology for a single homogeneous shipment more closely resembles per unit, rather than ad-valorem, transport costs.

Table 2 reports estimates of equations (11) and (12) using our two sets of instruments. We find strong support for the extended Alchian-Allen hypotheses on transport costs and tariffs in all specifications. Doubling freight costs increases average f.o.b. prices by 80 to 141 percent, depending on the estimation strategy. Doubling ad-valorem tariffs reduces average f.o.b. prices 146-256 percent. The magnitude of the tariff elasticity is worth emphasizing. It implies that a tariff is more than proportionally offset by reductions in the f.o.b. price, so that the delivered price actually drops after the tariff is imposed. In Section IV we examine whether these magnitudes are consistent with pricing-to-market.

In Table 2 we pool over all commodity categories, but our theory suggests Alchian-Allen effects might vary across commodities. In particular, the magnitude of the derivatives in equations (3) and (4) depend on the difference in prices for high and low quality goods. To test this, we re-estimate equation (12) separately for each 3-digit HS category, using shipment weight and distance as instruments.²² We plot the elasticity of prices with respect to freight rates on the vertical axis in Figure 1. Every 3-digit category shows significant Alchian-Allen effects.

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 total variation in prices: the lowest (highest) price available from the exporter must be at least as low (high) as the lowest (highest) observed average price. This means we can use the variation in average prices to determine a minimum possible range for total variation. We

²² 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 point estimates are very similar to the 3-digit results.

calculate the distribution of $(p_{ijk} / \overline{p_{jk}})$ for each 3-digit category. We represent price dispersion for each 3-digit category using the 90th/10th percentile split in the distribution, and plot this dispersion on the horizontal axis in Figure 1. The positive relationship plotted in Figure 1 indicates that our theory's prediction for cross-commodity variation is borne out. Alchian-Allen effects are strongest for those commodities in which we observe the widest variation in prices.

IV. Alternative explanations: Pricing-to-Market.

An important literature on pricing-to-market (PTM) explains price variation over destinations as a function of monopoly markups. These markups covary negatively with ad-valorem price shifters such as tariffs or exchange rate movements. We extend the theory on PTM to include per unit charges and examine whether our empirical findings in Table 2 (the positive coefficient on transportation costs and the magnitude of the negative coefficient on tariffs) could be explained entirely on the basis of PTM.

Put another way, we have treated observed trade prices as weighted averages of prices for goods of varying quality. With perfect competition, the price of any one quality is equal to its 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. Suppose instead that an exporter-commodity consists of a single product produced by a monopoly firm. Could we explain our empirical findings as pricing to market by that monopoly firm?

Consider a setup similar to Brander and Spencer (1984), extended to include both per unit and ad-valorem costs. A monopolist produces a good with constant marginal costs, c , and sells it to a foreign market that is segmented from home. The delivered price includes a per unit charge

f , and an ad-valorem cost t , as in equation (2). Consumer preferences are characterized by the inverse demand function $p^*(q)$. The monopolist chooses a profit-maximizing quantity, yielding first and second order conditions

$$(13) \quad \pi_q = \frac{1}{t}(p^*)' q + \frac{p^*(q) - f}{t} - c = 0$$

$$(14) \quad \pi_{qq} = \frac{1}{t} \left((p^*)'' q + 2(p^*)' \right) < 0$$

where $(p^*)' = \frac{\partial p^*(q)}{\partial q}$, and $(p^*)'' = \frac{\partial^2 p^*(q)}{\partial q \partial q}$. Using (13) we can determine the effect of both

barriers on the optimal quantity

$$(15) \quad \frac{\partial q}{\partial t} \equiv q_t = \frac{c}{(p^*)'' q + 2(p^*)'} < 0$$

$$\frac{\partial q}{\partial f} \equiv q_f = \frac{1}{(p^*)'' q + 2(p^*)'} < 0$$

The effect of t and f on the delivered price is determined by the change in price along the inverse demand curve due to change in quantity

$$(16) \quad p_t^* = (p^*)' q_t$$

$$p_f^* = (p^*)' q_f$$

By substituting (15) into (16), and expressing the price change in terms of elasticities, we find a pass-through elasticity for tariffs given by

$$(17) \quad \varepsilon_{pt} = \left[\frac{1}{R+2} \right] \frac{c}{p} - 1.$$

where R is a measure of the relative convexity of demand,

$R = (p^*)'' q / (p^*)'$. The second order conditions require $1/(R+2) > 0$, which bounds $\varepsilon_{pt} > -1$.

In Table 2 we estimate $\varepsilon_{pt} < -1$. A rise in tariffs decreases f.o.b. prices more than proportionally, so that the delivered price inclusive of the tariff actually falls. This cannot be explained by PTM.

The elasticity of the f.o.b. price with respect to the transportation cost is

$$(18) \quad \varepsilon_{pf} = \frac{f}{pt} \left(\left[\frac{1}{R+2} \right] - 1 \right)$$

If $R > -1$ (linear demands imply $R=0$) the expression in (18) is negative, and a per unit transportation cost will reduce the f.o.b. price of the good. For the case of constant elasticity of demand, $\sigma = -p^* / (p^*)' q$, we have the standard markup rule given by

$$(19) \quad \left[\frac{1}{R+2} \right] = \frac{\sigma}{\sigma-1} > 1$$

In this case (and for any inverse demands with relative convexity $R < -1$), a per unit transportation cost increases the f.o.b. price of the good.²³

The empirical literature does not provide us with estimates of R . However, we do have estimates of the pass-through elasticity taken from the previous literature on pricing-to-market, and using $\hat{\varepsilon}_{pt}$ we can sign equation (18). Solve (17) for $1/(R+2)$, and substitute into (18)

$$(20) \quad \varepsilon_{pf} = \frac{f}{pt} \left[(\varepsilon_{pt} + 1) \frac{p}{c} - 1 \right]$$

²³ Note that if $f > 0$, $\varepsilon_{pt} < 0$ even in the CES case. The monopolist charges a c.i.f. price that is a markup on all costs, including transport. , $p^* = (\sigma/\sigma-1)(ct+f)$. Net off trade costs to get the f.o.b. price, and express it as a markup over marginal costs, we have $p/c = (\sigma/\sigma-1) + f/ct(\sigma-1)$. Substituting the expression for p/c back into equation (18) yields $\varepsilon_{pt} < 0$.

The sign of (20) depends on the term in square brackets. Goldberg and Knetter (1997) report an average pass-through elasticity taken from the PTM literature $\hat{\varepsilon}_{pt} = -0.5$.²⁴ In this case, the elasticity of price with respect to transport costs will only be positive if the markup of f.o.b. price over marginal cost $p/c > 2$.

How big must markups be in order to yield our lower end estimates of $\hat{\varepsilon}_{pf} = 0.8$? Again use $\hat{\varepsilon}_{pt} = -0.5$, and use means from our data to calculate $f/pt = 0.05$. The f.o.b. price would then have to be 34 times larger than marginal costs of production. This seems implausibly high.

We can therefore rule out the possibility that PTM alone explains our results. This is not to say that it is unimportant, and observed pricing variation in the world may incorporate both PTM and Alchian-Allen effects. In fact, a model that combined PTM and Alchian-Allen effects could explain why we estimate (in absolute magnitudes) a larger coefficient on tariffs than on transport costs. For tariffs, PTM and Alchian-Allen effects reinforce each other. For transport costs, they work against each other. Our results do raise a question, which we leave to another day: how much of the observed pass through behavior found in the previous literature is really monopoly pricing, and how much reflects changes in quality composition?

V. Conclusion

We extend 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

²⁴ The estimates are actually elasticities of prices with respect to exchange rate changes. Feenstra (1989) demonstrates the theoretical equivalence between tariffs and exchange rates for pricing-to-market. Our Table 3 estimates do provide an elasticity of price with respect to tariffs, though its magnitude is inconsistent with pricing-to-market. Substituting our estimate $\hat{\varepsilon}_{pt} < -1$ into (20) yields $\hat{\varepsilon}_{pf} < 0$, contradicting our findings on transportation costs.

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. F.o.b. prices vary considerably over importers and provide strong support for the theory: doubling freight costs increases f.o.b. prices by 80 to 141 percent; doubling ad-valorem tariffs decreases f.o.b. prices by 146 to 256 percent.

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 of the “iceberg” form, or 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 discuss and dismiss an alternative explanation of our empirical findings in terms of pricing-to-market by monopoly firms. We extend PTM theory to include per unit transport costs, and show how markups covary with tariffs and transport costs. The magnitude of our tariff elasticity is inconsistent with PTM. The sign and magnitude of our transport cost elasticity is inconsistent with PTM unless one assumes extremely large monopoly markups.

Finally, the price effects we observe are quite large, implying significant variation in relative demands across destinations. But some remote countries face high transportation costs (and low tariffs) when exporting to all destinations. This suggests a possibility that we leave to future work: could Alchian-Allen effects on relative demand lead to a general equilibrium response in the supply of quality?

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Table 1. Determinants of Freight Costs

Dependent variable: ln(freight cost)	Variables (in logs)			R ²	Obs.
	Price β	Distance δ	Quantity ω		
OLS, all countries	0.64 (0.0012)	0.26 (0.0019)	-0.12 (0.0005)	0.64	275398
IV, all countries	0.61 (0.0048)	0.25 (0.0020)	-0.18 (0.0022)	--	254031
OLS, US sample	0.716 (0.0017)	0.114 (0.0017)	-0.219 (0.0024)	0.83	299409
IV, US sample	0.125 (0.0138)	0.221 (0.0050)	-0.480 (0.0142)	--	277756

Notes:

1. Estimating equation (10):

$$\ln f_{ijk} - \overline{\ln f_k} = a + \beta (\ln p_{ijk} - \overline{\ln p_k}) + \omega (\ln WGT_{ijk} - \overline{\ln WGT_k}) + \delta (\ln DIST_{ij} - \overline{\ln DIST_k}) + (\varepsilon_{ijk} - \overline{\varepsilon_k})$$

2. IV estimates: price and quantity are instrumented by tariffs, and exporter and importer GDP per capita.

Table 2. Alchian Allen Effects on Prices.

Dependent variable: ln(price)	Variables (in logs)				Obs.
	Freight cost ϕ	Tariff τ	GDP per capita (importer) γ_1	GDP per capita (exporter) γ_2	
Instruments: shipment weight and distance.					
Eqn (11) – All variables commodity differenced	0.798 (.0023)	-1.56 (.0368)	0.46 (.0044)	0.20 (.0029)	254031
Eqn (12) – All variables exporter - commodity differenced	0.84 (.0026)	-1.46 (.0289)	0.53 (.0036)	--	275398
Instruments: lagged values of price					
Eqn (11) – All variables commodity differenced	1.33 (.0072)	-2.56 (.0787)	0.34 (.0092)	-0.03 (.0067)	91989
Eqn (12) – All variables exporter - commodity differenced	1.41 (.0144)	-2.28 (.0689)	0.62 (.0087)	--	100118

Notes:

1. Estimating equation (11)

$$(\ln p_{ijk} - \overline{\ln p_k}) = \phi(\ln f_{ijk} - \overline{\ln f_k}) + \tau(\ln t_{ijk} - \overline{\ln t_k}) + \gamma_1(\ln y_i - \overline{\ln y_k}) + \gamma_2(\ln y_j - \overline{\ln y_k}) + (e_{ijk} - \overline{e_k})$$

2. Estimating equation (12)

$$(\ln p_{ijk} - \overline{\ln p_{jk}}) = \phi(\ln f_{ijk} - \overline{\ln f_{jk}}) + \tau(\ln t_{ijk} - \overline{\ln t_{jk}}) + \gamma_1(\ln y_i - \overline{\ln y_{jk}}) + (e_{ijk} - \overline{e_{jk}})$$

Fig.1 Commodity Level Alchian-Allen Estimates as a Function of the Price Range.

