Subcontractors for Tractors: Theory and Evidence on Flexible Specialization, Supplier Selection, and Contracting*

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Abstract

We develop a simple model of flexible specialization under demand uncertainty. A buyer faces multiple suppliers with heterogeneous types to supply customized parts. The more specific a seller's assets are to the buyer, the higher is surplus within the relationship but the lower is the seller's flexibility to cater to the outside market. Higher quality suppliers have a greater likelihood of selling outside and so this cost is greater for them. Therefore even if a buyer typically prefers high types, some low type suppliers might be kept as marginal suppliers because of their greater willingness to invest more in assets specific to the buyer. We then examine a primary dataset on contracts between the largest tractor assembler in Pakistan and its suppliers and examine how the extent of asset specificity affects contractual outcomes such as prices and distribution of orders and find evidence that the more dedicated suppliers are indeed of lower quality.

1 Introduction

Many industries, particularly in developing countries, are characterized neither by vertically integrated firms nor by a set of independent buyers and suppliers but as *networks.* Suppliers provide specialized inputs to several buyers selling related but different products and buyers have more than one supplier for the same input. The resulting investment pattern on the part of suppliers has been characterized by flexible specialization and is considered to be an optimal response to de-

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mand uncertainty and costly capacity-building or inventory-holding.[1] In such environments there is considerable variation in the terms of the contracts faced by a set of sellers who differ in terms of how specific their assets are with respect to the main buyer.[2]

While there is a large literature on the determinants of the boundaries of the firm that highlights the importance of relationship specific investments, we know very little about how relationship-specific investments affect contracts when the boundaries of the firm are given.[3] Moreover, the existing literature treats specificity as being driven purely by technology. In a network or cluster setting, given that investment is characterized by flexible specialization, the degree of asset specificity with respect to any particular buyer is also partly a matter of choice.

In this paper we address these questions both theoretically and empirically. We look at an environment characterized by high uncertainty, weak contracting, and costly capacity building. This description fits the industrial sector of most developing countries quite well, although the relevance of the framework is not limited to these countries. We take the existence of buyer-seller networks as given and address two main questions: do suppliers of the same product who differ in how specific their assets are with respect to the same buyer, receive different prices and distribution of orders? What governs the variation in how specific a supplier's assets are in relation to one buyer?[4] We then illustrate this model through an empirical examination using primary data on contracts between one large buyer, Millat Tractors Limited (MTL), the largest and oldest tractor-producing firm in Pakistan, and its suppliers who vary in terms of how dedicated their assets are in relation to MTL. Following local custom we will call the buyer the "assembler", and the suppliers, "vendors".

Our theoretical model has three key ingredients. First, relationship-specific investments (as opposed to general investments) increase the surplus within the relationship, but lower the flexibility of a vendor to cater to the outside market, which is costly when demand is uncertain. Second, vendors are of different "types" i.e., ex ante qualities. Holding the level of investment constant, higher types generate a higher level of surplus both within the relationship and in the outside market. Third, higher types are more likely to find a buyer in the outside market. Because of the

[1] See Piore and Sabel (1984) for a discussion of flexible specialization and Kranton and Minehart (2000) for a formal analysis of when such networks are optimal relative to vertical integration.

[2] See, for example, Asanuma (1989) for a case study of the Japanese auto-manufacturing industry. In section 2 we review other studies on this topic.

[3] See Hart (1995) and Holmström and Roberts (1998) for excellent reviews of the transactions costs and property rights literature on the boundaries of the firm.

[4] Kranton and Minehart (2000) analyze the choice between vertical integration and networks of suppliers in model with flexible specialization, and the strategic investment incentives of individual firms that lead to their formation. Our paper shares with this paper the focus on the advantage of having flexible assets in the presence of demand uncertainty and costliness in maintaining capacity but focuses on a different and complementary set of questions.

first and the third features, higher types face a greater marginal cost of undertaking relation-specific investments. Thus for the same level of orders, higher types invest less than lower types. Therefore the model predicts that even if the assembler prefers high types in general, some low type vendors might be kept as marginal suppliers because of their greater willingness to invest in assets specific to the buyer, especially when demand is very uncertain.

The model is then used to examine MTL and its network of suppliers by making use of a primary dataset we collected on a sample of annual vendor-product specific contracts between MTL and its vendors for a period of ten years. The MTL data is attractive for several reasons. First, the focus on a single large buyer ensures that the comparison between contracts is meaningful. Second, we have detailed contractual outcomes including prices paid to a supplier for a given product (tractor part) and quantities scheduled every quarter for each product (henceforth "part") from the supplier for over a decade. Finally, given the assembler has multiple vendors supplying the same part, we are able to make cleaner comparisons by contrasting contracts between two vendors with different degrees of specificity but which supply the *same* part. Unlike a majority of the empirical literature on relationship-specific investments, our comparisons are therefore not confounded with other effects that may be specific to a product yet not related to relationship specificity. Our measure of specificity is the vendor's response to what fraction of it's machinery will go to waste if MTL stops buying from it and this measure is confirmed through various means such as relating it to a vendor's production processes.

We find, as predicted in the model and in the anecdotal literature on such networks, that there is substantial variation in how suppliers are treated - prices differ by as much as 25% and quantities by a factor of three across different vendors supplying the same part in the same year. Upon further examination we find that "tied" vendors (those that choose higher levels of specific investments) are the ones that get treated as second preference vendors, not only in terms of receiving more unstable and lower orders but lower prices as well.[5] While we also find that tied vendors have lower unit production costs, which might explain why they receive lower prices, other things being the same, the cheaper vendor should be made the first-preference vendors. It turns out that cost is not the only consideration of the assembler. It cares a great deal about timely and defect-free delivery. This suggests that type (ex ante quality) differences between vendors can explain why MTL does not treat the cheaper tied vendor as its first preference vendor. Indeed, we find that vendors with

[5] Asanuma (1989) uses the same terms in his case study of the Japanese auto-industry where he reports a similar hierarchy of subcontractors in terms of distribution of orders.

greater asset-specificity perform worse both in terms of timely and defect-free delivery. In terms of our theoretical model, low type vendors as capacity buffers because they are more willing to both undertake higher levels of specific investment and face greater uncertainty.

Our work is related to the theoretical literature on property-rights. The key distinction is that in our set up only the vendors undertake investments, and so optimal ownership is not the key question. Also, unlike our model, in this literature specific investment is purely technology driven, and firm heterogeneity and selection issues are not emphasized.

Our work is closely related to the empirical literature on asset specificity and how it affects the nature of contracting.[6] In this literature, the effect of asset specificity is typically shown either on contract duration (e.g., Joskow, 1987) or on certain contract provisions (e.g., Lyons , 1994 on the use of formal contracts, Gonzales, Arrunada and Fernandez, 2000 on extent of subcontracting, Woodruff, 2002 on the likelihood of vertical integration, and Baker and Hubbard, 2004 on the pattern of asset ownership). While we too study the effect of asset specificity on contracts, given the environment we have, the dependent variables we focus on are the prices and quantities of orders, and their variability over time and across subcontractors. This way, our work complements this literature. More generally, our work is related to the recent empirical literature on contracting where controlling for unobserved heterogeneity is an important theme (Chiappori and Salanie, 2003).

Finally, we view our work as a contribution to the emerging literature on contracting and organizational choice in the industrial sector in developing countries. The presence of significant uncertainty and transactions costs in these economies provide a fertile ground for testing many predictions of the theory of contracts and organizations. While a rich and growing empirical literature on contracting and organizational choice exists in the context of agriculture in developing countries, there is relatively little work in the context of industry (exceptions include Banerjee and Duflo, 2000, McMillan and Woodruff, 1999, and Banerjee and Munshi, 2004).[7]

The plan of the paper is as follows. In section 2 we discuss the key features of the environment drawing on several case studies on subcontracting in buyer-seller networks from different parts of the world. In section 3 we present the theoretical model. In section 4 we examine the case of MTL and is supplier network and interpret our empirical findings in terms of the theoretical model. Section 5 concludes.

[6] Chiappori and Salanie (2003) and Shelanski and Klein (1995) provide reviews of this literature.
[7] See Mookherjee (1999) for a survey.

2 Key Features of the Environment

In this section we discuss some key features of buyer-seller networks that motivate our formal model.

In these networks a buyer typically has multiple suppliers for the *same* product and sellers are treated differently by the buyer both in terms of quantity supplied and price obtained. Such networks are well documented in the auto industry particularly in East Asian economies. Chung (1999) mentions that in the Korean automobile industry, "each component was supplied by an average of 3.3 subcontractors in 1998". Our examination of Millat Tractors in Pakistan also shows that on average this assembler has 2.3 suppliers for each part. Such multiplicity is also fairly common in developed economies. Milgrom and Roberts (1997), and Forker (1997) discuss the presence of multiple subcontractors in auto and aerospace industries respectively.

More interestingly, the multiple sellers are often of different quality and in turn are treated differently by the buyer. Case studies of the Japanese auto industry (Asanuma,1989) discuss different tiers of suppliers with "first" and "second" preference ones. Park, et. al (2001) give a detailed account of how assemblers in the Korean automotive industry develop elaborate ratings of the suppliers.

This quality variation in suppliers often represents a quality-price trade-off. Callahan (2000) examines Canadian, Mexican US suppliers in a variety of industries and notes that while Mexican suppliers were seen as less capable, less cooperative and lower in quality performance, "nevertheless, the low cost of the Mexican parts made them cost-effective". While such a trade-off is not surprising, what is less apparent is why buyers choose to have both low and high quality suppliers for the same part rather than just prefer one type. This is one of the key issues we will examine in our formal model. Moreover, in addition to differences in price, several case studies document that sellers also face different quantity orders. In Korea, Chung (1999, 2001) notes that the brunt of the industry's uneven demand is borne by the smaller suppliers. Most of the shocks are passed onto the smaller suppliers. Asanuma (1989) notes that American automakers retained a large number of marginal suppliers and gave them orders only intermittently.

Such differential supply becomes particularly relevant in developing economies as they face high demand uncertainty. Hanson (1995) points out in the Mexican apparel industry that uncertainty associated with shifting tastes and resulting order changes were important in the rise of subcontracting networks. Chung (1999) documents how these network relationships were key to the automakers' response to dealing with the huge uncertainty in the aftermath of the Asian financial crisis. In our examination of the tractor industry in Pakistan, we find large yearly fluctuations in tractor sales in the economy (see Figure 1). Moreover these demand shocks are generally driven by a variety idiosyncratic factors. In the Pakistani tractor industry they include unexpected changes in the interest rates on government loans to farmers to fund tractor purchases, tariff and pricing policy changes, and weather shocks.

Variations in relationship-specific investments of suppliers in a network relative to a specific buyer is an important feature of networks. Such investments lead to asset-specificity, including both physical capital and human capital specificity. These are thought to lead to lower costs and improved quality within a relationship, but some loss of flexibility in selling to other buyers.

Physical capital specificity appears in the type of machinery used — general-purpose machines vs. special purpose machines, specific tooling dies vs. general purpose assets like presses (Milgrom and Roberts, 1997) — and the choice of the manufacturing process, e.g., how a machine is "tooled". General-purpose equipment has to be "tooled" in certain ways before producing a specific part. In machining, tooling is essentially calibrating a machine so that it produces the finished part according to particular specifications. In cases where computerized machinery is uncommon such as in the Pakistani auto industry, such tooling is done manually through trial and error and involves considerable time and effort, and learning-by-doing. Moreover, since specialized machine manufacturers do not always exist locally in developing economies, at times a supplier has to develop a specialized machine.[8]

Human capital specificity takes the from of *relationship-specific skills* as in the Japanese auto-industry (Asanuma, 1989) - these are skills that the supplier needs to develop to respond efficiently to the specific needs of a particular buyer. Forker (1997) in his aerospace example points out that less tangible aspects of the relationship such as friendships with purchasing personnel are all forms of asset specificity. In the Pakistani context, the skilled labor embodied in tooling machines to produce particular products, and the sellers' costs incurred in making their operations and organizational setup compatible to that of the buyer are also such forms of human capital specificity.

An aspect of such relation-specific investments that is apparent in case studies but has received little theoretical attention is that such specificity is not only driven by technology, but is often a choice of the supplier and can vary even in producing the same product. An example from our study of the tractor industry is a multi-drill boring unit. While this machinery can only be used to

[8] For example, one of the vendors we interviewed in the Pakistani auto industry had developed a special press just to create a specific part for its main buyer.

produce a restricted range of parts, according to the suppliers we interviewed it increased accuracy by up to 35% as compared to using the more general purpose standard single-drill boring units.

Once we recognize that specific investments may partly be a matter of choice, this raises questions regarding the circumstances under which such a choice is made or whether certain types of suppliers choose specific investments.

More often than not specificity choices are affected by the degree of uncertainty in the environment — stable demand allows the use of dedicated machinery. In contrast,when faced with volatility in demand (both volume and product mix), suppliers prefer flexible manufacturing processes that allow them to produce smaller volumes and a larger product mix. German and Roth (1997) discuss such choices facing automotive engine valve suppliers in Argentina who face a more uncertain environment than some of their global competitors. They prefer a process that is more flexible in that tooling and other fixed costs are lower, and so it is easier to shift from one product to another, but variable costs are higher (e.g., it requires more machining work to achieve the desired level of precision). The latter suppliers choose processes that require a large investment in tooling (i.e., large fixed costs), but are very efficient for producing large volumes.

In addition to uncertainty, suppliers of different quality may also choose different levels of specific investments. Forker (1997) points out that while suppliers that are more dependent on their main customer are cheaper, they often have problems with quality of the components produced. Similarly, Chung (1999) suggests that in the Korean automobile case it is the lower rung suppliers who are more dedicated. Our analysis of the Pakistani tractor industry yields similar results.

3 The Model

The model focuses on the relationship between a single assembler, and its vendors. Everyone is assumed to be risk-neutral. The assembler is unable to make some parts in-house and needs to outsource. Vendors produce parts that are then converted into output using some technology by the assembler. For simplicity, we assume that there is only one part that the assembler needs from vendors. The production technology involves the assembler using one unit of this part to produce one unit of the final good.

An assembler and a vendor can establish a relationship. This allows the vendor to produce a customized part to the assembler. Alternatively, the vendor can sell generic parts in the outside market to any buyer that may knock on its door. Similarly, an assembler can buy generic parts from the outside market.

The assembler faces uncertain demand: with probability $\alpha \in [0,1]$ demand is high (= 2 units) and with probability $1-\alpha$, demand is low (= 1 unit). Each vendor has the capacity to produce one unit of the part, but until that capacity constraint is reached, unit costs are constant and do not depend on the level of production. Given our specification of demand facing the assembler, this directly implies that it would need multiple (in the current setting, two) vendors if it wishes to supply the full amount that is demanded in each state of the world. Therefore, the answer to the question as to *why* there are multiple vendors follows directly from the assumption of a particularly simple form of decreasing returns to scale in our model.

Vendors are of two types, high or low, i.e., $\theta_i \in \{\underline{\theta}, \bar{\theta}\}$ where $1 \geq \bar{\theta} > \underline{\theta} \geq 0$. Let $\triangle\theta \equiv \bar{\theta} - \underline{\theta}$. We will use the normalization $\bar{\theta} + \underline{\theta} = 1$ which is without loss of generality. We assume that the type of vendor i, θ_i, is known and observable to all parties, i.e., there is no learning or adverse selection. There are many vendors of both types in the population. The higher the type of the vendor, the higher is the surplus within the vendor-assembler relationship. Also, higher type vendors have a higher expected outside option since they are more versatile and can cater to different types of buyers.

A vendor who has established a relationship with the assembler can undertake some relationship-specific investment (henceforth, investment) that enhances the value of trade within the relationship, in the form of higher quality and/or lower costs. Let $x \in [0,1]$ denote the level of investment undertaken by a vendor. We interpret x as the percentage of his total capacity that a vendor keeps tooled up for producing the customized part to the assembler on demand. The rest of the capacity is kept flexible so that it can be used to produce generic parts.

The (*ex post*) joint surplus from trade between the assembler and a vendor of type θ is $S(x,\theta) = a + b\theta + x$ where $a > 1$, and $b > 0$.[9] That is, joint surplus is increasing in the quality of the vendor as well as the extent of relationship-specific investment undertaken by him. The (*ex ante*) cost of undertaking the specific investment is $c(x) = \frac{1}{2}x^2$.

The assembler has the option of buying a generic part from the market. In this market the assembler as well as the vendors are price takers. One unit of a generic part procured from the outside market yields an expected net surplus of γ to the assembler where $\gamma \in (0, \frac{1}{2})$.

[9] For our analysis it does not make any difference as to whether the investment improves quality or reduces costs or both. It is easy to modify the above set up slightly to allow for a separate quality-enhancement and a cost reduction effect. For example, for a vendor of type θ who has undertaken an investment level of x, suppose the unit cost of production is $\gamma(x) = 1 - \gamma x$ where $\gamma \in (0,1)$. Correspondingly, suppose that the (expected) revenue of the assembler is $R(x) = a - 1 + b\theta + (1-\gamma)x$. This ensures that $S(x,\theta) = R(x,\theta) - \gamma(x)$.

A vendor, whether or not he has established a relationship with the assembler, has the option of selling generic parts in the outside market. This provides vendors with an outside option in their dealings with the assembler.

The outside option faced by a vendor of type θ whose investment vis a vis the assembler is x, is $u(x, \theta) = \lambda\theta(1 - x)$. Vendors earn an exogenously given expected surplus of λ per unit of sales in the outside market where $\lambda \in (0, \frac{1}{2})$.[10] Higher quality vendors face higher expected returns in the market for generic parts because they can produce a wider range of generic parts and as a result, are more likely to find a prospective buyer. In particular, θ is the probability a vendor of type θ finds a buyer in the market for generic parts. Finally, a vendor who has established a relationship with the assembler and has made some relationship specific investments has a disadvantage in selling the generic part in the outside market relative to an "unattached" vendor because a part of his capacity is not flexible, and is less suitable to produce generic parts on demand. In particular, he can produce $1 - x$ units of the generic part using the flexible part of his capacity.

As $a > 1$, it is more efficient for an assembler to establish a relationship with a vendor and get a customized part (which yields a joint surplus which is at least as large as a per unit) rather than relying on the outside market for a generic part (which yields a joint surplus of $\gamma + \lambda$ per unit which is less than 1).

3.1 The First-Best

We first analyze the case where the investment is contractible and is chosen the maximize the expected joint surplus of the assembler and the vendor. Let $\beta \leq 1$ be the demand faced by a vendor from the assembler, to be chosen endogenously. This can be either a certain demand of β units, or the probability that he is called to supply one whole unit. We will use the latter interpretation. If x is contractible and the assembler plans to buy β units of the customized part from a vendor of type θ, x will be chosen to maximize *ex ante* expected joint surplus between the vendor and the assembler. Under the first-best how the assembler and the vendor split this surplus among themselves has no allocational implications. If demand from the assembler is not forthcoming (which has probability $1 - \beta$) then a vendor sells generic parts in the outside market. Therefore, the *ex ante* expected joint surplus between the vendor and the assembler is::

$$s(x) = \beta S(x, \theta) + (1 - \beta)u(x, \theta) - c(x).$$

[10] In general, λ could depend on θ.

which yields the following optimal choice of x:

$$x^*(\beta,\theta) = \max\{\beta - (1-\beta)\lambda\theta, 0\}. \tag{1}$$

As $\beta \leq 1$, $x^*(\beta,\theta) < 1$. Let $\hat{\beta}(\theta)$ be the critical value of β such that $x^* = 0$, i.e., $\hat{\beta}(\theta) = \frac{\lambda\theta}{1+\lambda\theta}$. Notice that $\hat{\beta}(\theta) < 1$ and that it is increasing in θ. Our first result follows immediately upon inspecting (1):

Proposition 1: *Under the first-best:*

(i) *The level of investment is increasing in the level of orders.*

(ii) *The higher is the type of the vendor, the lower is the level of investment for the same level of order.*

(iii) *For the range of orders where both types of vendors invest this gap decreases as the level of orders increases and disappears when the level of orders is* 1*.*

The first part of the result follows from the fact that the specific investment is useful only when the asset is used to produce for the assembler, and so the level of specific investment is increasing in the level of orders. The second part follows from the fact that the marginal social return from relationship specific investment is lower the higher is a vendor's type. These vendors are more likely to get an outside offer and therefore the marginal cost of constraining themselves to one particular buyer is higher for them. The fact that low type vendors invest more for the same expected order than high type vendors make them potentially attractive. The third part follows from the fact that as the level of orders (β) increases, the outside option gets lower and lower weight, and so the gap between the investment of a high type and a low type vendor shrinks so long as they are both choosing positive levels of investment. When $\beta = 1$ because the outside option gets no weight in the choice of investment, this gap disappears.

Next we characterize how an assembler allocates its orders among vendors. To do so, we need to find out how the net surplus between the assembler and a vendor depends on the level and distribution of orders. By being outside the relationship and serving only the outside market a vendor can earn $u(\theta) = \max_x u(x,\theta) - c(x) = \lambda\theta$. This is the outside option of a vendor of type θ. Given the equilibrium value of x_i, the equilibrium value of the net *ex ante* expected surplus from the relationship is the expected surplus in the relationship net of the outside option and cost of undertaking the investment:

$$s^*(\beta,\theta) \equiv \left\{\beta S(x^*(\beta,\theta),\theta) + (1-\beta)u(x^*(\beta,\theta),\theta) - \frac{1}{2}\left(x^*(\beta,\theta)\right)^2\right\} - u(\theta).$$

This is the maximum expected net surplus that is generated if a vendor of type θ and the assembler decide to enter into a relationship. By our assumptions concerning the parameters a and b $S(x,\theta) > u(x,\theta)$ and so it directly follows that $s^*(\beta,\theta) > 0$. Now we are ready to state:

Proposition 2: *Under the first-best the assembler would give one vendor a certain order of* 1, *and the other vendor an order of* 1 *with probability* α *and* 0 *with probability* $1-\alpha$.

Proof: See the appendix.

This result is driven by the fact that $s^*(\beta,\theta)$ is increasing and convex in β. Under our assumptions it is more profitable for a vendor to trade with the assembler than with the outside market. An increase in orders increases the weight attached to trade with the assembler relative to trade with the outside market, and hence increases expected joint surplus within the relationship. There is also an indirect effect of increasing orders via the level of specific investment, x, for the range of β for which there is an interior solution. But under the first-best x is chosen to maximize joint surplus and so this effect is zero by the envelope theorem. Next let us consider the second-order effect of increasing orders on $s^*(\beta,\theta)$. The first-order effect of increasing orders is equal to the (per unit) *ex post* surplus from trade between the vendor and the assembler (i.e., $S(x,\theta)-u(x,\theta)$). This itself is increasing in β for the range of β for which there is an interior solution and so here $s^*(\beta,\theta)$ is strictly convex in β. For the range of β for which there is a corner solution, this is a constant and so $s^*(\beta,\theta)$ is linear (and so weakly convex) in β.[11]

Since the expected surplus within a relationship is convex in the level of orders, it is efficient to distribute the orders among the minimum possible number of vendors. Given that the maximum demand is for two units of the part, and each vendor has a capacity of one, we can restrict attention to two vendors. Since these vendors can in principle be of different types, we introduce the following function:

$$s^*(\beta) = \max\{s^*(\beta,\underline{\theta}), s^*(\beta,\bar{\theta})\}.$$

[11] Analytically, this property is similar to the profit function of a competitive firm being convex in the output price.

This is the upper envelope of the net *ex ante* expected surplus from the relationship when the type of vendor of the vendor can be chosen for any given level of order β.

We will refer to the vendor with a high and stable order as the "first-preference" vendor and the vendor with a lower and fluctuating order as the "second-preference" vendor. This result shows is that it is in fact optimal to have a "first-preference" and a "second-preference" vendor as opposed to spreading the orders between the vendors in a more equal manner. This is depicted in Figure 2. Since the type specific joint surplus functions are increasing and convex, so must be their upper envelope $s^*(\beta)$. This is the relevant net joint surplus function given that the assembler can choose different types of vendors for different ranges of orders. Therefore the assembler should try to place as much order with one vendor as possible, and pass the residual order to another vendor. Since each vendor has a capacity constraint of one unit of output, in equilibrium the assembler buys from more than one vendor - otherwise he would buy everything from one vendor.

Our next result characterizes the choice of the type of vendor:

Proposition 3: *Under the first-best, there exists* $\overline{b} > \lambda$ *such that:*

(i) For $b \leq \lambda$ *both the first and second-preference vendors are going to be low types.*

(ii) For $b > \overline{b}$ *both the first and second-preference vendors are going to be high types.*

(iii) For $b \in (\lambda, \overline{b}]$ *the first-preference vendor is going to be a high type vendor. The second preference vendor is going to be a high type vendor if* α *is very low or very high but a low type vendor otherwise.*

Proof: See the appendix.

The key parameter in this characterization is b, which is the marginal return from higher quality inside the relationship. The marginal return from higher quality outside the relationship is λ. When b is lower than λ, while higher quality is preferred both inside the relationship and outside, it is more valuable outside. As a result, it is not efficient for the assembler to try to attract high type vendors. Indeed, as we noted earlier, in this case even if we ignore investment, low types would be preferred. But since they invest at least as much as the high types for any given level of orders (Proposition 1) considering investment reinforces the preference for low type vendors. With $b > \lambda$ there is, a trade off. Now the marginal social return from higher quality, ignoring investment, is higher inside the relationship than outside. But high types invest less for the same level of orders than low types. When b is high enough (i.e., $b \geq \overline{b}$) the first effect dominates and the high types are always preferred. But for intermediate values of b (namely, $b \in (\lambda,\ \bar{b})$) it is possible that low types become attractive since they invest more. Recall from Proposition 1 that the gap between the investment levels of the high type and the low type decreases as the level of orders increases. For very low levels of orders neither type of vendors invest, and so for $b > \lambda$ the high types would be preferred. For high levels of orders, the gap between the investments of high and low types is very small, and so once again the high types would be preferred. For intermediate levels of orders the gap between the investments of high and low types is large, and low types will be preferred when $b \in (\lambda, \bar{b})$.

Recall from Proposition 2 that one vendor is going to be given a certain order (the "first-preference" vendor) and the other vendor is going to be given the residual order α (the "second-preference" vendor). So for $b \leq \lambda$ both the first-preference and the second-preference are going to be low types, and similarly, for $b \geq \lambda$, both the first-preference and the second-preference are going to be high types. For intermediate values of b, the first-preference vendor is going to be a high type. If α is high the second-preference vendor is going to be a high type and the same is true if α is low. But if α takes an intermediate value, the second-preference vendor will be a low type vendor. Since α is the probability of the high demand state, and we are considering a binary distribution, the variance is $\alpha(1-\alpha)$ which is high for intermediate values of α and low for high or low values of α. So this result tells us that the presence of greater uncertainty makes having a mixed portfolio of vendors more likely.

Now we proceed to characterize the investment levels undertaken by first and second-preference vendors:

> **Proposition 4:** *The first-preference vendor will always undertake a higher level of investment than the second-preference vendor.*
>
> **Proof**: See the appendix.

If both first-preference and second-preference vendors happen to be the same type, naturally the former will invest more than the latter. However, if the first-preference vendor is high type, and the second-preference vendor is low type then the comparison is not straightforward - for the same order the high type invests less than the low type, but he happens to get a higher order. It turns out that in this particular instance, the comparison is actually straightforward. Being first-preference means you always receive an order of 1, and so the outside option gets no weight in the choice of investment under the first-best. Indeed, when the order is 1, the investment of a high type and a low type are the same (Proposition 1). But we know that a low type vendor with order $\alpha < 1$ invests less than a low type vendor with order 1. So even when the first-preference vendor is a high type and the second-preference vendor is a low type, in the first-best the former will invest more than the latter.

Remark: Suppose we allow the specific investment and the type of the vendor to be substitutes or complements *within* the relationship as opposed to just being substitutes in the outside option. Does this qualitatively affect our results? Let us modify the above model such that $S(x, \theta) = a + b\theta + (1 - k\theta)\, x$ where the parameter $k \in (0, 1)$ allows x and θ be complements ($k < 0$) or substitutes ($k > 0$) as opposed to being independent ($k = 0$) which is what we assumed in the benchmark model. This yields the following optimal choice of x:

$$x^*(\beta, \theta) = \max\left\{\beta\,(1 - k\theta) - (1 - \beta)\lambda\theta, 0\right\}.$$

Clearly, if the investment and the type of the vendor are complements (substitutes) then the investment advantage of the low types decrease (increase) compared to the above model but the basic classification of alternative cases remain valid. However, when the investment and the type of the vendor are substitutes ($\delta > 0$) there is an interesting implication for the case where both high types and low types are chosen in equilibrium. Now the first-preference vendor (a high type) will choose an investment level of $1 - k\bar{\theta}$. However, the second-preference vendor (a low type) will choose an investment level of $\alpha\,(1 - k\underline{\theta}) - (1 - \alpha)\lambda\underline{\theta}$. This raises the interesting possibility that the second-preference vendor might invest more even though he has a lower demand. For example, let $\bar{\theta} = 1$ and $\underline{\theta} = 0$. Then the required condition for this becomes $(1 - \alpha) < k$ which is possible given our assumptions about the parameters.

3.2 The Second Best

Now we turn to the case where x is subject to transactions costs.[12] Following the Grossman-Hart-Moore property-rights framework let us assume that x is observable but not verifiable. The price for a vendor is negotiated after the investments are sunk, and the parties are assumed to adopt the Nash bargaining solution. The assembler bargains with each vendor separately and independently. If bargaining breaks down with a particular vendor after the investment is undertaken, the vendor

[12] While the choice of a machine (general or special purpose) can in principle be contracted upon, it is harder to contract on how machines are to be tooled etc. Moreover, in developing country environments where such networks are quite prevalent, contracts are typically incomplete partly due to the high costs of formal contracting.

is able to walk out of the relationship and earn its *ex post* outside option $u(x, \theta)$.[13]

The assembler can, in principle, find another vendor and buy the customized part from him. There are several costs of doing this. For example, there are costs of screening and training a new vendor (which we have not modeled), the new vendor would not have had the time to invest, and there will be some loss of surplus due to delay in delivering to the final consumer.[14] For simplicity we have assumed that these costs are significant and so if bargaining breaks down, the assembler has to buy a generic part from the outside market which yields a surplus of γ per unit.[15]

The gross *ex post* surplus within the relationship if trade takes place is $S(x, \theta)$. The vendor's share of the *ex post* surplus from dealing with the assembler per unit of the part conditional on trade taking place (which can be interpreted as the price) using the standard Nash-bargaining formula is:

$$\pi = \frac{S(x,\theta) + u(x,\theta) - \gamma}{2}. \tag{2}$$

The assembler's share of the *ex post* surplus in his relationship with the vendor per unit of the part conditional on trade taking place is:

$$\Pi = \frac{S(x,\theta) - u(x,\theta) + \gamma}{2}. \tag{3}$$

The vendor would choose x to maximize:

$$\beta\pi + (1-\beta)u(x,\theta) - c(x).$$

The vendor's optimal choice of x is therefore given by:

$$x^{SB}(\beta,\theta) = \max\left\{\frac{\beta}{2} - (1 - \frac{\beta}{2})\lambda\theta, 0\right\}. \tag{4}$$

where the superscript SB indicates that this is the optimal second-best allocation. As $\beta \leq 1$,

[13] Why doesn't the assembler own the asset instead of the vendors owning it? In this model, we are assuming that the assembler does not undertake any significant specific investments with a specific vendor, the *ex ante* choice of which could be affected by *ex post* bargaining. This is justified by the institutional setting. MTL makes tractors based on blueprints provided by MTL's foreign partner, Massey-Ferguson and gives the vendor an imported sample of a relevant part. Any technological support provided is not specific to a particular vendor, but to all vendors that supply that part. Given this, ownership by the assembler will only help to reduce the vendor's share of *ex post* surplus, which would dampen his investment incentives.

[14] According to Williamson's notion of relationship-specificity, even if one party does not undertake any up front expenditures at all, his *ex ante* relationship-specific investment could just be the choice of a partner or a standard or anything else that limits his later options.

[15] This *ex post* bargaining power of the vendor is perfectly consistent with *ex ante* competition among vendors to be able to trade with the assembler, and is a consequence of relationship specificity.

$x^{SB}(\beta, \theta) < 1$. From the previous section, we know that if $\frac{\beta}{2} \leq \hat{\beta}(\theta)$, or, $\beta \leq 2\hat{\beta}(\theta) = \frac{2\lambda\theta}{1+\lambda\theta}$ then $x^{SB} = 0$. Let $\beta_0 \equiv 2\hat{\beta}(\underline{\theta})$ and $\beta_1 \equiv 2\hat{\beta}(\overline{\theta})$. As $\hat{\beta}(\theta)$ is increasing in θ, $\beta_0 < \beta_1$. As $\lambda < 1$ and $\theta \leq 1$, $\beta_1 < 1$. That is, high type vendors undertake *some* positive level of investment in the second-best situation when demand is high enough. For $\beta > \beta_1$ the investment levels of both types of vendors are positive, for $\beta_1 \geq \beta > \beta_0$, the investment level of the high type is 0, but that of the low type is positive, and for $\beta_0 \geq \beta \geq 0$ the investment levels of both types are zero.

Proposition 5: *Under the second-best:*

(i) The level of investment is lower for any given level of orders and any given vendor type compared to the first-best.

(ii) The level of investment is increasing in the level of orders.

(iii) The higher is the type of the vendor, the lower is the level of investment for the same level of order.

(iv) The gap between the investment levels of the two types of vendors for any given level of orders is larger than the first-best.

(v) For the range of orders where both types of vendors invest this gap decreases as the level of orders increases and but stays positive even when the level of orders is 1.

Proof: See the appendix.

The first part of the result illustrates the well known under-investment result due to hold-up. A vendor underinvests because he expects a fraction of the surplus from his investment to be appropriated by the assembler in the *ex post* bargaining game, as in standard hold-up models. In addition, in our set up a higher level of investment directly reduces his outside option and this reinforces the under-investment effect. The second and the third parts are similar to that in the previous section. The fourth part follows from the fact that as investment increases, the value of a high type vendor's outside option decreases at a higher rate compared to a low type vendor and because of this, their marginal loss from investing is higher. This was true also under the first-best, but now a decrease in the outside option leads to both lower flexibility and lower bargaining power. As a result, for the same level of orders, high type vendors invest less than low types, as under the first-best but the gap between their investment levels is higher. For the fifth part, as before as demand increases the weight assigned to the outside option falls and so the gap between the investments of the high type and the low type decreases. However, even when demand is certain (i.e., $\beta = 1$) the outside option gets some weight unlike in the first-best, because of the value of the outside option in bargaining and as a result, the gap between the investment levels of the two types of vendors remain positive.

Using (3), let the surplus *per unit of the part* of the assembler from trading with a vendor whose type is θ and who gets an order of β be denoted as:

$$\Pi(\beta, \theta) \equiv \frac{\{a + b\theta - \lambda\theta\} + (1 + \lambda\theta)\, x^{SB}(\beta, \theta) + \gamma}{2}. \tag{5}$$

Let

$$\Pi^*(\beta) = \max\{\Pi(\beta, \underline{\theta}), \Pi(\beta, \bar{\theta})\}$$

denote the upper envelope of the surplus per unit schedule facing the assembler who can choose the type of vendor that is most profitable to deal with for any given level of order β. The expected total surplus of the assembler from a vendor who is given an order of β is

$$\beta\Pi^*(\beta).$$

When deciding on how to allocate orders, the assembler will consider this function, and not expected joint surplus as under the first-best. Now we are ready to characterize how should an assembler distribute its orders among the vendors under the second-best:

> **Proposition 6:** *Under the second-best the optimal way to distribute orders would be to give one vendor a certain order of* 1, *and the other vendor an order of* 1 *with probability* α *and* 0 *with probability* $1 - \alpha$.
>
> **Proof**: See the appendix.

The intuition is as follows. Unlike the first best, the assembler does not care about *ex ante* expected joint surplus anymore. Rather, he cares about his share of the surplus in the post-investment bargaining game, i.e., $\beta\Pi^*(\beta)$. The greater is the level of orders, the higher is the investment effect and the higher is the assembler's *per unit* surplus, $\Pi^*(\beta)$. In our set up, this relationship is linear - either per unit surplus does not depend on the level of orders (the level of investment has a corner solution) or it is linearly increasing in the level of orders because the level of investment is an increasing and linear function of the level of orders. This implies that the per unit of surplus of an assembler from a given type of vendor is an increasing and (weakly) convex function of the level of orders. Since the assembler can choose the type of a vendor, the per unit surplus schedule facing the assembler is the upper envelope of the per unit surplus for each type of vendor, which is therefore a convex function. Since the *level* of surplus is just the rate of surplus times the level of orders, it too must be a convex and increasing function of the level of orders. Given this the way the assembler should distribute its orders among the vendors follows using the same arguments as under the first-best.

The following result characterizes the choice of the type of vendor:

Proposition 7: *Under the second-best there exists $b' \in (\lambda, \bar{b})$ (where $\bar{b}$ is as defined in Proposition 3) such that:*

(i) For $b \leq \lambda$ both the first and second-preference vendors are going to be low types.

(ii) For $b \geq \bar{b}$ both the first and second-preference vendors are going to be high types.

(iii) For $b \in (b', \bar{b})$ where $b' < \bar{b}$ the first-preference vendor is going to be a high type vendor and the second preference vendor is going to be a high type vendor if α is very low or very high but a low type vendor otherwise.

(iv) *For $b \in (\lambda, b']$ the first-preference vendor is going to be a low type vendor and the second preference vendor is going to be a high type vendor if α is very low, but a low type vendor otherwise.*

Proof: See the appendix.

The only qualitative difference with the corresponding result for the first-best case (Proposition 3) is in part (iv). Now it is possible to have a low type vendor as the first-preference vendor. This is because two additional factors diminish the attraction of high type vendors relative to low type vendors under the second-best. First, the assembler has lower bargaining power in dealing with them and so even if the high types invested as much as the low types for the same order, the relative attraction of the high type is less. Second, the investment gap between high types and low types is greater than under the first-best (Proposition 5(iv)). In particular, even when $\beta = 1$, it is possible to prefer a low type vendor which was not possible under the first-best. The intuition for parts (i) and (ii) of this result, corresponding to low and high values of b, is similar to that of the corresponding result under the first-best. The case described in part (ii) is depicted in Figure 3(a). For intermediate values of b ($\bar{b} > b > \lambda$) there are several possibilities. When both types of vendors do not invest high types are preferred, as before. Over the range where low type vendors invest but high type vendors do not, the relative attractiveness of low type vendors increases as their investment is increasing in β. It reaches a maximum at the level of demand $\beta = \beta_1$ from which point onwards the high type starts investing. For the range where both types of vendors choose positive investment levels (i.e., $\beta \in [\beta_1, 1]$), Π increases at a faster rate with respect to β for the high type vendor. This follows directly from the fact that an increase in the size of the order β leads to a greater increase in x for higher types since their investment is more sensitive (in a negative way) to the weight assigned to the outside option. This means, the relative attractiveness of low type vendors fall in this range. Figure 3(b) considers the case $b' < b \leq \bar{b}$, and here low types are preferred for intermediate values of β but high types are preferred for high and low values of β. Here the first preference vendor would be high type, for intermediate values of α the second preference vendor would be low type, and for very high or very low values of α, it would be a high type. Finally, Figure 3(c) considers the case $\lambda < b \leq b'$, and here high types are preferred only for low values of β (when no one invests), otherwise low types are preferred. In this case the first preference vendor would be low type, and the second preference vendor would be a low type for high or intermediate values of α and a high type for low values of α.

Finally, we proceed to characterize the investment levels undertaken by first and second-preference vendors:

Proposition 8: *The first-preference vendor may undertake a lower level of investment than the second-preference vendor.*

Proof: See the appendix.

Like in the previous section if both first-preference and second-preference vendors happen to be the same type, naturally the former will invest more than the latter. However there even if the first-preference vendor was high type and the second-preference vendor was low type, the former would invest more than the latter. The reason was, in the first-best when the order is 1, the investment of a high type and a low type are the same. But under the second best, as Proposition 5 indicates, even when demand is certain (i.e., $\beta = 1$) a high type vendor invests less than what a low type vendor would have invested for the same level of orders.

4 Empirical Evidence

Are the above features of buyer-seller networks present in the data? Specifically, does one see first and second preference sellers and sellers of different types supplying the same product? Do sellers differ in how dedicated their assets are to the buyer? Are these related to seller type? How are orders allocated across sellers with different levels of investment-specificity and type?

In order to address these questions so we examine an actual buyer-seller network - Millat Tractors Limited (MTL), the largest tractor manufacturer in Pakistan - and its suppliers, henceforth referred to as its vendors. We should caution that this empirical case is not presented in order to test the model since that is beyond its scope, but rather as an illustration of the predictions highlighted in the model that are characteristic of buyer-seller networks.

4.1 Data

MTL is licensed to produce two models of Massey-Ferguson tractors and does so by mostly outsourcing (only 7 out of the 500 tractor parts are manufactured in-house [16]) to a rich and stable base of 200 local vendors with very little turnover in these vendors. The vendors are selected by MTL after a rigorous examination of their technological capability and MTL is therefore aware of each vendor's strengths and weaknesses i.e. vendor type, as in the model above, is known to MTL. MTL mostly has multiple vendors for each part, while each vendor typically also supplies to several buyers, including other tractor assemblers, the market for replacement parts, and automobile manufacturers.

Once a vendor is approved to supply a particular product - a tractor part - MTL negotiates a price for the part and issues a tentative quantity order. While the price agreed upon for the period of the contract (generally a year) is binding for both parties, there is no commitment on quantity.[17] The supply schedule is issued each quarter and is determined by demand conditions. As such, in our empirical analysis we will focus not only on the negotiated price but also on both the quantity scheduled each quarter and the quantity that the vendor delivers.

There are two aspects of a vendor's supply that MTL is concerned about - part and delivery quality. A key quality issue is a part failing to meet measurement specifications. The incorrect

[16] A medium sized tractor assembled by MTL requires around 900 components, of which 400 are imported. A *component* normally comprises of several *parts* (e.g., a set of bolts required for one wheel is treated as a component by MTL). The vast majority of local vendors produce metalwork parts. In 1994, 54% of the total value of parts procured by MTL was from local vendors. See Amir, Isert and Khan (1995).

[17] Price renegotiations within the contract period happen rarely unless there is some large unexpected change in input prices (e.g., a hike in raw steel prices).

measurements result either from vendor error or using equipment beyond their acceptable lifetime. As such MTL has elaborate part-quality control mechanisms ranging from tests of random samples for each batch supplied to assembly-line fitting and field problems. Timely delivery of the quantity ordered is the other major concern for MTL. This is especially important since MTL requires all parts to assemble its final product and so, inventories aside, a single vendor may hold up MTL's production line if it delays delivery.

An important feature is the high degree of uncertainty in yearly sales the tractor industry in Pakistan faces. Figure 1 shows this high degree of volatility during 1989-99. There are several reasons for this uncertainty, ranging from erratic government policy (concerning the financing of tractor purchases by government banks, imports, taxes) to demand fluctuations driven by unstable agricultural output growth.

We employ two data sources. The primary dataset consists of part-specific contracts between MTL and its vendors during 1989-99 and additional part level information from the archives at MTL. The data provides negotiated price and quarterly quantity scheduled and received by vendor for each part. The parts are representative, ranging from low priced simple products such as tractor clips (Rs. 0.2) to high priced complex products such as a transmission case (Rs. 5306). This dataset is merged with a survey of the automobile industry vendors conducted by the Lahore University of Management Sciences (LUMS) in 1997 to construct vendor attributes. This leaves us with a sample of 28 MTL vendors.

We further restrict our analysis to parts for which MTL buys from more than one of the 28 vendors in our sample. This restriction allows us to address the main question of interest, namely how prices and quantities vary across vendors supplying the *same* part. Otherwise we would be comparing vendors that supply different products, and even though we allow for a part-specific intercept, we would not be able to separate out the effect of a firm's characteristics from choices such as its degree of relationship specificity. The drawback is the smaller sample size — we are left with 19 of the 28 vendors supplying 39 different parts — produces potentially higher standard errors.

Table 1 gives the definitions and summary statistics for the main variables used. The primary outcomes of interest are the annual price for each part and vendor, and the quantity ordered and subsequently received from each vendor. Note that we do not have any direct measure of the type of the vendor (i.e. θ in the model). As such the primary explanatory variable is the degree of relationship specific investments (x in the model) undertaken by the vendor. This is measured as the percentage of the vendor's physical assets/equipment that would become idle i.e. would have to be scrapped if MTL stopped buying from it.[18]

Given the importance of specificity, it is important that our measure capture the degree of specific investments and not an omitted factor such as a vendor's dependence on MTL or confidence in its own abilities. We provide several checks for this. First, using MTL engineers ranking of technological processes, we show that our measure is higher for processes that are more likely to require dedicated investments. Vendors involved in machining and forging, both high-specificity processes, declared specificity measures of 62% and 66% whereas those that only did casting, a low-specificity process, had much lower specificity measures. Second, we check for an obvious misinterpretation with "sales reliance" on MTL and find that a vendor's percentage sales to MTL and its declared specificity are not correlated, suggesting that this misinterpretation is not an issue.[19]

4.2 Empirical Specification

Our data restriction to parts with multiple sample vendors allows us to use part and time fixed effects to contrast contractual outcomes for two different vendors supplying the same part in the same year. This is the tightest restriction we can apply, though at the cost of reducing sample size. Part fixed effects control for potentially important and confounding aspects specific to the part (such as its technological nature, how critical it is, the number of vendors supplying it provided that this does not change over the sample period etc.) and time fixed effects control for common period-specific shocks such as inflation, demand, and government policy changes. We will be estimating equations of the form:

$$C_{ijt} = \alpha_i + \tau_t + \sum_j \beta_j X_j + error. \tag{6}$$

C_{ijt} = (level of) contractual feature/outcome for part i, vendor j, in period (year or quarter)

[18] Alternately this measure can be thought of as the level of quasi-rents (see Williamson 1985) generated by the specific-investment. Andrabi, Ghatak and Khwaja (2004) consider this alternate interpretation and find that it leads to a similar but more involved explanation of the empirical findings.

[19] One might expect that a vendor that has less dedicated assets to MTL will have fewer sales to MTL and vice versa. Neither relation is necessarily true. First, a vendor could be making all its sales to MTL but it could be using generic machinery to produce the parts and as such have low specificity. As a result, if MTL stops buying from it, it could switch to another buyer. Indeed, in our field interviews we found a vendor involved in machining that makes all its sales to MTL, but since it uses lathe machines that can easily be switched to produce parts for another buyer, it reported a specificity of zero. Now consider the converse. It would seem that a vendor that has a high specificity should be making most of its sales to MTL. However, this is not necessarily the case. A vendor could be very tied to MTL but could still be making most of its sales for the part it produces for MTL in the replacement market instead of directly to MTL.

t; X_j = time-invariant vendor characteristic; α_i = part-specific intercept and τ_t = period-specific (year/quarter) intercept.

One caveat is that this specification treats vendor characteristics as time invariant. At a practical level this is dictated by the fact that we have information on some vendor characteristics such as specificity for only one year. However, we are not unduly concerned since these attributes do not change substantially over the short time period under study (11 years, with 96% of the data coming from the period 1993-1999) as supported in cases where we have another year of vendor characteristics (correlations between vendor size observations in 1985, 1990 and 1995 are all above 0.95 and highly significant). Moreover, even if they do change, as long as they change uniformly i.e. vendors do not keep switching rank there is unlikely to be any systematic bias in our results.

The main results are summarized below. We generally look at the logarithm of these variables rather than levels, because different products have very different levels of prices and quantities, and the aim of the analysis is to explain the percentage changes in level differences across vendors (i.e., log differences) and not the absolute level of differences. While we are primarily interested in vendor specificity, we also include other vendor attributes as robustness checks. For example, controlling for firm age[20] and size allows us to take into account learning-by-doing effects or economies of scale affects. For all regression tables, the first column reports the result with a smaller set of basic controls (specificity, age, size) and the second column adds more controls (the distance from MTL, a city dummy). The estimated coefficients below are from the last column unless noted otherwise.

4.3 Results

An important prediction of the model and a feature highlighted in descriptions of buyer-seller networks is that there is price and quantity variation across vendors supplying the same part i.e., there are first and second preference vendors.

Before presenting the regressions results we establish the importance of such differential treatment both in terms of price and quantity. Restricting to cases where two vendors are supplying a *given part in the same year* we get that on average one vendor gets a 25% higher price than the other. Doing the same for quantity supplied shows that on average a vendor is scheduled three times as much as another vendor supplying the *same part in the same year*. There are also substantial yearly fluctuations in aggregate quantity for each part. We compute the coefficient of variation

[20] We also have data on years of relationship. It is highly correlated with the age of a vendor and our results are similar if we use this variable instead of age.

(CV) for the quarterly quantity supplied by the vendor for each part in our multiple-vendor restricted sample. The mean value of the part-CV for all the parts is 0.99 for (quarterly) scheduled quantity, suggesting that there is considerable variation in orders and that MTL passes a significant part of its total sales shock to its vendors. This variation could be partly capturing growth over time but taking out secular time trends shows that this is not the case.

Does investment in relationship-specific assets lead to greater surplus in terms of lower production costs? This was one of the assumptions in the model and it is instructive to see whether it is empirically supported. Fortunately for a sub-sample of parts we have internal cost estimates generated by MTL engineers. These estimates calculate how much it costs a particular vendor to produce the given part. Since MTL engineers are intimately familiar with the machines and production processes used by each vendor, these cost estimates vary for the same part across different vendors and provides a way for us to test whether vendors with lower specificity have lower production costs. Table 2 shows that this is indeed the case: An increase in specificity from 0 to 100% decreases level costs by 15%. Alternatively, a standard deviation increase in specificity lowers costs by 6.6%.[21] Production costs also fall in the age and size of the vendor suggesting learning by doing and scale economies and lending further credibility to the cost results.

The significant variation in price and quantity across vendors supplying the same part in a given year suggests differential treatment. We examine what type of vendors are treated preferentially by MTL. In particular, how is this preferential treatment related to the degree of specific investments undertaken by the vendor.

Tables 3-4 first examine preferential treatment in terms of the stability of orders given to vendors. Table 3 collapses the data to the vendor-part level by computing the coefficient of variation for the quarterly quantity ordered for each part from a given vendor over time. The results show that vendors that undertake greater specific investments ("tied" vendors) are given a more unstable order. A standard deviation increase in vendor specificity is associated with a 4.1-5.4% higher coefficient of variation. However the result weakens with city and distance controls, partly because of the small sample size.

Table 4 presents an alternate way of examining order instability by making use of the time-dimension of the data and asking how MTL passes on its overall demand variability to its vendors. It does so by computing the elasticity of each vendor's scheduled quantity to MTL's total demand

[21] In general, the magnitude of the effect is calculated from a one standard deviation increase in specificity starting at 0 specificity. The percentage change is then evaluated at mean of the dependent variable.

for the given part. It shows that a standard deviation increase in tiedness is associated with a 3.7 *percentage points* increase in elasticity (i.e. from an elasticity of 0.739 to 0.776). Therefore, as before, we see that tied vendors face a more fluctuating order i.e. are treated as second preference.

Table 5 presents a simpler specification than in table 4 and shows that tied vendors also get a lower level of orders. A standard deviation increase in tiedness is associated with a 5.5%-13.4% drop in the quantity scheduled from the vendor. While the magnitude is much larger with city and distance controls, the standard errors also increase.

Finally, Table 6 shows that tied vendors also get a lower price. An increase in the measure of specificity from 0 to 100 decreases price by 19%; a standard deviation increase in tiedness results in a 7.9% lower price level.[22] These regressions assume that the quality of the lot supplied does not affect current prices. This is reasonable as the price of each part to be supplied by a vendor is agreed upon for the entire year before delivery begins. Also note that while tied vendors had lower costs, the price is even lower suggesting that these vendors receive a lower per unit return.

Our results have shown that tied vendors, despite choosing to invest in assets specific to MTL, are treated as second preference vendors as they receive more unstable orders and lower order levels and prices for the parts they supply. This result seems puzzling. If anything, MTL should prefer and hence better treat those vendors that choose to invest in specific assets particularly since we have shown that this leads to lower costs of production. This apparent puzzle may be reconciled in light of the theory. Recall that once we admit there is vendor heterogeneity, the choice of how much specific-investments to make may also reflect a vendor type i.e. all else being equal, low type vendors choose to be more tied to MTL. Under high final product uncertainty (which MTL faces - recall Figure 1) we also get that low type vendors may choose a higher level of specific-investments despite getting a lower order (case iii of Propositions 3 and 7). While we do not have direct measures of vendor type, we can check whether this explanation is consistent with the empirical evidence by directly looking at the final quality of the tied vendors.[23] Since all else being equal, investing in more dedicated assets should raise quality, if the final quality of tied vendors is in fact lower, this lends strong support that vendors of lower type (i.e. initial quality) are more likely to choose

[22] Note that we have an unbalanced panel i.e. for all years the set of parts are not the same. One concern is that our results are based only on a comparison of the same part for two vendors across *different* years. However, we can check for this by allowing for interacted part-year dummy variables. Doing so gives similar results allaying our concern, although, as expected, the standard errors are higher.

[23] In general it is not easy to separate the effects of vendor type from its choice of specifity without a direct measure of the former. Using vendor fixed effects is unlikely to help since both quality and asset-specificity are likely to be time-invariant. Having an instrument for vendor type may not solve the problem since, as the model shows, this would also affect the choice of specificity.

specific-investments and is able to reconcile our previous empirical results in light of the model. Our results below show that this is indeed the case.

Table 7 shows that tied vendors' supply is of lower quality. A standard deviation increase in tiedness is associated with a 43.6% increase in the proportion of a vendor's order that is rejected because it fails to meet MTL's quality standards. However it should be noted that this proportion is generally quite low, with a mean value of 1% (the increase is from 1% to 1.43%) suggesting that in general MTL's quality control is fairly effective.

MTL is also concerned about delivery performance i.e. does a vendor deliver the amount that is ordered and is this delivery on time. We can examine this question since, in addition to the quantity ordered from the vendor, we also have the quantity that the vendor delivered in response to the order. Tables 8-11 take a closer look at delivery performance and reveal that tied vendors perform worse on this dimension as well.

Table 8 shows that a tied vendor is less responsive to the quantity MTL ordered from it. A standard deviation increase in tiedness is associated with a 8.7 percentage points decrease (from 0.474 to 0.387) in elasticity of the quantity a vendor delivers with respect to the quantity that MTL asked from it. A possible concern could be that since tied vendors are given a more unstable order this is to be expected. However, as Table 9 confirms, tied vendors are also less responsive to MTL's overall demand for a given part.

Tables 10 and 11 provide further evidence for the poorer delivery performance of tied vendors. They show that tied vendors are more likely to both under and oversupply quantity (i.e. the quantity received from them is less or more than what MTL ordered). Table 10 shows that a standard deviation increase in tiedness is associated with a 24% increase in the quantity that is undersupplied by the vendor. Table 11 shows that a standard deviation increase in specificity is associated with a 10% increase in quantity oversupplied, although this result is not robust to city and distance controls.

4.4 Alternative Explanations

The MTL case reveals that vendors choosing greater specific-investments are treated as second preference. This result can be explained by the theoretical model which shows low type vendors are more willing to undertake specific investments. Moreover, as the model illustrates, under demand uncertainty MTL deals with such low types not only because they invest in specific-assets but also because they are willing to act as capacity buffers i.e. MTL passes on more of its shock to them. Thus in equilibrium we see MTL buying from both types - high quality but less tied and low quality but more tied vendors. While the empirical case is not meant as a test of the model, it is nevertheless worth asking whether there are simpler alternative explanations of the MTL findings.

Can an explanation be provided without relying on the role of specific investments? Since tied vendors are willing to be treated as marginal vendors an explanation would require that they are of lower *ex ante* quality i.e. lower type. We have already addressed a concern that our specificity measure may not reflect specific-investments but that lower type vendors report a higher measure because their outside options are worse. The fact that our measure is correlated with the specificity expected under different manufacturing processes used by vendors and that it is not correlated to their sales to MTL, suggests that this concern is unwarranted. Even if this were true, a further argument would be needed to explain why MTL deals with both high and low quality vendors. Vendor shortage or type unobservability is unlikely since MTL carefully selects its pool of 200 active vendors out of a population of over 2,000 vendors. Moreover, even for its existing high quality vendors, our data shows that neither are their sales exclusively to MTL, nor are they producing near plant capacity, further suggesting that MTL *chooses* not to have them supply more.[24]

Does one require that specific investments hurt outside options? What if we only assume this investment and vendor type are substitutes *within* the relationship? In this case while high types invest less than low types as before, the investment gap between the high and low types is now *decreasing* in the level of orders. This means if low types are hired at all, they are more likely to be used as first-preference vendors which is inconsistent with our empirical findings.

Finally, what if there is no ex ante vendor heterogeneity (i.e. only one vendor type) but being tied has the exact opposite effect from what we have assumed i.e. it lowers ex post quality? This seems implausible both because it is contrary to the literature and because our data suggests there are direct gains from being tied in terms of lower production costs. Moreover, if being tied did lead to a worsening of a vendor's quality, why would it ever choose to be tied, especially since it is treated worse in terms of prices and quantities ordered if it becomes tied. These is no evidence that MTL provides any other assistance to tied vendors such as loans etc.[25]

[24] Alternatively, one could make restrictive assumptions on the demand function facing MTL such that it demands both low and high quality parts from its vendors. For instance, MTL might be selling two different qualities of the same tractor with more variable demand from customers who value quality less. However, this seems quite unlikely since MTL can only sell tractors at uniform prices predetermined by the government and it is implausible that it can consistently "fool" less quality conscious consumers to buy inferior tractors at the same price. Also, there is no evidence that MTL employs any non-price mechanisms of discriminating among different types of customers.

[25] The data shows MTL provides little financial support to vendors and there is no correlation between financial assistance received and the extent of specificity.

5 Conclusion

The relationship between a tractor assembling firm in Pakistan and its subcontractors offers important insights about contracting and asset specificity within a buyer-supplier network. The presence of demand uncertainty makes undertaking relationship-specific investments costly on the part of suppliers. This cost is likely to be more, the more able and versatile the supplier. Therefore there is a chance for low quality suppliers to survive because of their greater willingness to undertake specific investments and this may explain why there continues to be seller heterogeneity and differential treatment in buyer-seller networks. In the case of MTL tractors, this explains the puzzle we observe that the buyer treats suppliers with greater asset-specificity as marginal suppliers even though they are cheaper.

Our work also suggests that asset specificity should not always be viewed as purely technology-driven which has been the dominant view in the organizations literature. It may also capture heterogeneity among firms and this implies one has to be careful in interpreting the effect of asset-specificity on contractual and performance outcomes.

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Appendix

Proof of Proposition 2:

We prove this in two steps. First we show that $s^*(\beta,\theta)$ is an increasing and convex function of β. Next, we show that given this property, the assembler would give one vendor a certain order of 1, and the other vendor an order of 1 with probability α and 0 with probability $1-\alpha$.

Step 1: Recall that $s^*(\beta,\theta) = \beta(a + b\theta + x^*(\beta,\theta)) + (1-\beta)\lambda\theta(1 - x^*(\beta,\theta)) - \frac{1}{2}x^*(\beta,\theta)^2 - \lambda\theta$. Now $\beta x^*(\beta,\theta) - (1-\beta)\lambda\theta x^*(\beta,\theta) - \frac{1}{2}x^*(\beta,\theta)^2 = \{\beta - (1-\beta)\lambda\theta\}\, x^*(\beta,\theta) - \frac{1}{2}x^*(\beta,\theta)^2 = \frac{1}{2}x^*(\beta,\theta)^2$ using (1). Therefore, the expected joint surplus function can be written as

$$\begin{aligned} s^*(\beta,\theta) &= \beta\,(a+b\theta) - \lambda\theta \text{ for } \beta \leq \hat{\beta}(\theta) \\ &= \beta\,(a+b\theta) - \lambda\theta + \frac{1}{2}\{\beta - (1-\beta)\lambda\theta\}^2 \text{ for } \beta \geq \hat{\beta}(\theta). \end{aligned}$$

For $\beta \leq \hat{\beta}(\theta)$, $\frac{\partial s^*}{\partial \beta} = (a+b\theta) - \lambda\theta$. As $a \geq 1, b > 0, \theta < 1$ and $\lambda < 1$, this expression is strictly positive. Also, it is independent of β. For $\beta \geq \hat{\beta}(\theta)$, using the envelope theorem, $\frac{\partial s^*}{\partial \beta} = (a+b\theta) - \lambda\theta + \{\beta - (1-\beta)\lambda\theta\}(1+\lambda\theta) > 0$. Differentiating with respect to β again we find that $s^*(\beta,\theta)$ is strictly convex in β : $\frac{\partial^2 s^*}{\partial \beta^2} = (1+\lambda\theta)^2 > 0$. **QED**.

Step 2: By Step 1 the function $s^*(\beta,\theta)$ is convex and strictly so for $\beta > \hat{\beta}(\theta)$. As $s^*(\beta) = \max\{s(\beta,\underline{\theta}), s(\beta,\overline{\theta})\}$, it too is a convex function of β. If demand is high (with probability α), then each vendor will get an order of one unit and there is no allocation decision to make. If demand is low (with probability $1-\alpha$) then there is only one unit of order, and this needs to be distributed among the two vendors in some manner. Let one vendor get an order of one unit with probability δ and let the other vendor get an order of one unit with probability $1-\delta$. Therefore for one vendor the probability of getting an order of one unit is $\alpha + (1-\alpha)\delta$ and for the other vendor, this probability is $\alpha + (1-\alpha)(1-\delta)$. We will show that δ will be chosen to be 1. The total net surplus in dealing with these two vendors is $s^*(\alpha + (1-\alpha)\delta) + s^*(\alpha + (1-\alpha)(1-\delta))$. We claim $s^*(\alpha + (1-\alpha)\delta) + s^*(\alpha + (1-\alpha)(1-\delta)) \leq s^*(1) + s^*(\alpha)$. This is equivalent to the inequality $s^*(\alpha + (1-\alpha)\delta) - s^*(\alpha) \leq s^*(1) - s^*(\alpha + (1-\alpha)(1-\delta))$. Observe that $\alpha + (1-\alpha)\delta - \alpha = 1 - \{\alpha + (1-\alpha)(1-\delta)\} = (1-\alpha)\delta$. Given this the above inequality directly follows from the fact that $s^*(.)$ is a convex function. **QED**.

Proof of Proposition 3:

The net expected joint surplus consists of two components. One is independent of investment, namely, $\beta\,\{(a+b\theta) - \lambda\theta\}$. The other component depends on the investment, namely, $\frac{1}{2}\{\beta - (1-\beta)\lambda\theta\}^2$. The latter component is relevant only when demand exceeds some threshold level, i.e., $\beta \geq \hat{\beta}(\theta)$. As far as the former component is concerned, the difference between a high type and a low type vendor is $\beta\left\{\left(a + b\overline{\theta}\right) - \lambda\overline{\theta}\right\} - \beta\,\{(a + b\underline{\theta}) - \lambda\underline{\theta}\} = \beta\,(b-\lambda)\,\triangle\theta$ (using the fact that $\overline{\theta} + \underline{\theta} = 1$) which is positive, zero, or negative according as $b > \lambda, b = \lambda$ and $b < \lambda$.

Since low type vendors always invest more than high type vendors, if $b \leq \lambda$ then high type vendors will never be strictly preferred. From Proposition 2 we know that the first-preference vendor is going to be given a certain order of 1 and the second-preference vendor the residual order α. In this case both these vendors will be low type vendors.

Now we consider the case there $b > \lambda$. We need to consider three subcases depending on the level of orders, β.

Case 1: Low ranges of orders, i.e., $\beta \leq \hat{\beta}(\underline{\theta})$.

In this case $x^* = 0$ for both high and low type vendors and since $b > \lambda$ high type vendors would be chosen.

Case 2: Intermediate ranges of orders, i.e., $\hat{\beta}(\underline{\theta}) < \beta \leq \hat{\beta}(\bar{\theta})$.

In this case a high type vendor chooses a zero level of investment, but a low type vendor chooses a positive level of investment. Let $g(\beta) \equiv \frac{1}{2}\left\{\beta - (1-\beta)\lambda\underline{\theta}\right\}^2 - \beta(b-\lambda)\triangle\theta$. This is just the negative of the difference in surplus between high type vendors and low type vendors. Since $\frac{1}{2}\left\{\beta - (1-\beta)\lambda\underline{\theta}\right\}^2$ is increasing and convex in β, while $\beta(b-\lambda)\triangle\theta$ is linear, the maximum value of $g(\beta)$ is attained at $\hat{\beta}(\bar{\theta}) = \frac{\lambda\bar{\theta}}{1+\lambda\bar{\theta}}$ and is equal to $\frac{1}{2}\left(\frac{\lambda\triangle\theta}{1+\lambda\bar{\theta}}\right)^2 - \frac{\lambda\bar{\theta}}{1+\lambda\bar{\theta}}(b-\lambda)\triangle\theta$. The condition for this expression to be positive, in which case low types are preferred, is $b < \lambda + \frac{1}{2}\frac{\lambda}{1+\lambda\bar{\theta}}\frac{\triangle\theta}{\bar{\theta}} \equiv \widetilde{b}$. In contrast, if $b \geq \widetilde{b}$ high types would be chosen.

Case 3: High ranges of orders, i.e., $\beta \geq \hat{\beta}(\bar{\theta})$.

Here $x^* > 0$ for both types of vendors. As low type vendors invest more than high type vendors for the same β, they generate a higher surplus if we consider only the part of joint surplus that is due to investment. This difference is equal to $\frac{1}{2}\{\beta - (1-\beta)\lambda\underline{\theta}\}^2 - \frac{1}{2}\left\{\beta - (1-\beta)\lambda\bar{\theta}\right\}^2 = (1-\beta)\lambda\{\ \beta - \frac{1}{2}(1-\beta)\lambda\}\triangle\theta$ (using the normalization $\bar{\theta} + \underline{\theta} = 1$). Let us compare this with the difference in surplus if we consider the part of joint surplus that is independent of investment, i.e., $\beta(b-\lambda)\triangle\theta$.

Let $f(\beta) \equiv (1-\beta)\lambda\{\ \beta - \frac{1}{2}(1-\beta)\lambda\}\triangle\theta - \beta(b-\lambda)\triangle\theta$. It is straightforward to check that $f(\beta)$ is a concave function of β, that it is increasing for $\beta \geq \hat{\beta}(\bar{\theta})$, decreasing for $\beta > \frac{1+\lambda}{2+\lambda} - \frac{b-\lambda}{\lambda(2+\lambda)}$, and achieves an (unconstrained) optimum at $\beta = \beta^* = \frac{1+\lambda}{2+\lambda} - \frac{b-\lambda}{\lambda(2+\lambda)}$.

The relevant range for β is $\beta \in [\hat{\beta}(\bar{\theta}), 1]$. At $\beta = \hat{\beta}(\bar{\theta})$, $\frac{1}{2}\left\{\beta - (1-\beta)\lambda\bar{\theta}\right\}^2 = 0$, and so $g(\hat{\beta}(\bar{\theta})) = f(\hat{\beta}(\bar{\theta}))$. The condition for $\beta^* \geq \hat{\beta}(\bar{\theta})$ is, upon simplification, $\lambda\frac{1+\lambda\underline{\theta}}{1+\lambda\bar{\theta}} \geq b - \lambda$ (using the fact that $(1-\bar{\theta}) = \underline{\theta}$). Let $\bar{b} \equiv \lambda + \lambda\frac{1+\lambda\underline{\theta}}{1+\lambda\bar{\theta}}$. We show that $\bar{b} > \widetilde{b}$. The condition for $\lambda\frac{1+\lambda\underline{\theta}}{1+\lambda\bar{\theta}}$ to exceed $\frac{1}{2}\frac{\lambda}{1+\lambda\bar{\theta}}\frac{\triangle\theta}{\bar{\theta}}$ is, upon simplification, $2(1+\lambda\underline{\theta}) > \frac{\triangle\theta}{\bar{\theta}}$. This is true since the left-hand side exceeds 2 while the right-hand side is bounded above by 1. Therefore, $\arg\max_{\beta\in[\hat{\beta}(\bar{\theta}),1]} f(\beta) = \beta^*$ for $b < \bar{b}$ and for $b \geq \bar{b}$, $\arg\max_{\beta\in[\hat{\beta}(\bar{\theta}),1]} f(\beta) = \hat{\beta}(\bar{\theta})$.

As $\bar{b} > \widetilde{b}$, there are three cases of interest: $b < \widetilde{b}$, $\widetilde{b} \leq b < \bar{b}$, and $b \geq \bar{b}$.

In the first case, $g(\hat{\beta}(\bar{\theta})) > 0$ and $f(\beta^*) > g(\hat{\beta}(\bar{\theta}))$. However for $\beta \geq \beta^*$, $f(\beta)$ is decreasing, and for $\beta = 1, f(\beta) < 0$. Therefore, by continuity there exists some $\tilde{\beta}_1$ that lies between β^* and 1 such that for $\beta \geq \tilde{\beta}_1$, high types are preferred. For $\beta \in [\hat{\beta}(\bar{\theta}), \tilde{\beta}_1]$ low types are preferred. From the analysis of *Case 2* above, and given that $g(\beta)$ is increasing an convex, again by continuity we know that there is some $\tilde{\beta}_0 \in [\hat{\beta}(\underline{\theta}), \hat{\beta}(\bar{\theta})]$ such that for $\beta \geq \tilde{\beta}_0$ low types are preferred, but for $\beta < \tilde{\beta}_0$, high types are preferred. Therefore, in this case low types are preferred for $\beta \in [\tilde{\beta}_0, \tilde{\beta}_1]$ and high types are preferred for $\beta < \tilde{\beta}_0$ and $\beta > \tilde{\beta}_1$.

In the second case, $g(\hat{\beta}(\bar{\theta})) < 0$, but $f(\beta^*) > 0$. Given that $f(\beta)$ is concave in the interval $[\hat{\beta}(\bar{\theta}), 1]$, by continuity there are two cutoff points $\tilde{\beta}_2$ and $\tilde{\beta}_3$ in this interval with $\hat{\beta}(\bar{\theta}) < \tilde{\beta}_2$ and $\tilde{\beta}_2 < \tilde{\beta}_3 < 1$, such that for $\hat{\beta}(\bar{\theta}) \leq \beta < \tilde{\beta}_2$ high types are preferred, for $\tilde{\beta}_2 \leq \beta < \tilde{\beta}_3$ low types are preferred, and for $\tilde{\beta}_3 \leq \beta < 1$, high types are preferred again.

In the third case, $\beta^* = \hat{\beta}(\bar{\theta})$ but as $b \geq \bar{b} > \widetilde{b}$, $f(\beta) < 0$ in the entire interval $\beta \in [\hat{\beta}(\bar{\theta}), 1]$. Therefore, in this case high types are preferred.

To sum up, there exists three threshold values of the parameter b, namely, $\lambda, \widetilde{b}$, and $\bar{b}$ such that $\bar{b} > \widetilde{b} > \lambda$. For $b \leq \lambda$ low types are preferred for all levels of orders. Therefore, both the first and the second preference vendors are low types in this case. For $b \geq \bar{b}$ high types are preferred for all levels of orders and so both the first and the second preference vendors are high types in this case. For $\lambda \leq b \leq \overline{b}$, there exists an interval $[\underline{\beta}, \overline{\beta}]$ where $\overline{\beta} < 1$ and $\underline{\beta} > 0$ such that low types are used for $\beta \in [\underline{\beta}, \overline{\beta}]$ and high types are preferred for $\beta \in [0, \underline{\beta}]$ and $\beta \in [\overline{\beta}, 1]$. For $\lambda \leq b < \widetilde{b}$, $\underline{\beta} = \tilde{\beta}_0$ and $\overline{\beta} = \tilde{\beta}_1$. For $\widetilde{b} \leq b < \overline{b}$, $\underline{\beta} = \tilde{\beta}_2$ and $\overline{\beta} = \tilde{\beta}_3$. In this case the first-preference vendors are going to be high type. The second-preference vendor gets the residual order α. If α is very high or low, the second-preference vendor is going to be a high type vendor. If α is neither too high nor too low then low type vendors are going to be chosen as second-preference vendors. **QED.**

Proof of Proposition 4: By Proposition 2 one vendor gets a certain order of 1, and the other vendor gets an order of 1 with probability α. So if they are of the same type, by Proposition 1 the one with the certain order will invest more. So let us consider the remaining possibility where the first-preference vendor is a high type vendor and the second-preference vendor is a low type vendor. Because the first-preference vendor gets a certain order of 1, by (1) the level of investment is 1. The second-preference vendor, who gets an order of α, chooses an investment level of $\alpha - (1-\alpha)\lambda\underline{\theta}$ which is clearly less than 1. **QED.**

Proof of Proposition 5: Parts (i)-(iii) follow upon inspecting (1) and (4). To prove (iv) let us calculate the difference in investment for the same order under the first-best and the second-best, $x^*(\beta,\theta) - x^{SB}(\beta,\theta) = \frac{\beta}{2}(1+\lambda\theta) > 0$. Since $x^*(\beta,\theta) - x^{SB}(\beta,\theta)$ is increasing in θ, the underinvestment problem is more serious for the high type vendors. The last part directly follows from:

$$x^{SB}(\beta,\underline{\theta}) - x^{SB}(\beta,\bar{\theta}) = \left(1-\frac{\beta}{2}\right)\lambda\triangle\theta \qquad \text{for } 1 \geq \beta \geq \beta_1. \tag{7}$$

$$= \left\{\frac{\beta}{2} - (1-\frac{\beta}{2})\lambda\underline{\theta}\right\} \qquad \text{for } \beta_1 \geq \beta \geq \beta_0. \tag{8}$$

$$= 0 \qquad \text{for } \beta_0 \geq \beta \geq 0. \tag{9}$$

QED.

Proof of Proposition 6: First we show that for $x^{SB}(\beta,\theta) = 0$, $\Pi(\beta,\theta)$ does not change as β changes, and for $x^{SB}(\beta,\theta) > 0$, $\Pi(\beta,\theta)$ is a linear and increasing function of β. The first part of the statement follows immediately from the fact that the only way β affects $\Pi(\beta,\theta)$ is through $x^{SB}(\beta,\theta)$. Now consider the case $x^{SB}(\beta,\theta) > 0$. Using (4) and (5) we find that for $\beta \geq \beta_0$, $\frac{\partial\Pi(\beta,\underline{\theta})}{\partial\beta} = (1+\lambda\underline{\theta})\frac{\partial x^{SB}(\beta,\underline{\theta})}{\partial\beta} = \frac{1}{4}(1+\lambda\underline{\theta})^2$. Similarly, for $\beta \geq \beta_1$, $\frac{\partial\Pi(\beta,\bar{\theta})}{\partial\beta} = (1+\lambda\bar{\theta})\frac{\partial x^{SB}(\beta,\bar{\theta})}{\partial\beta} = \frac{1}{4}(1+\lambda\bar{\theta})^2$. Therefore $\frac{\partial\Pi(\beta,\theta)}{\partial\beta}$ is positive and independent of β for $x^{SB}(\beta,\theta) > 0$. This implies that the function $\Pi(\beta,\theta)$ is a (weakly) convex function of β. Next, observe that as $\Pi^*(\beta) = \max\{\Pi(\beta,\underline{\theta}), \Pi(\beta,\bar{\theta})\}$, it too is a convex function of β. Given that Π^* is increasing in β, this immediately implies that $\beta\Pi^*(\beta)$ is convex in β. The rest of the proof is identical to that of Proposition 2 if we replace the function $s^*(\beta,\bar{\theta})$ with $\beta\Pi^*(\beta)$. **QED.**

Proof of Proposition 7: Consider $\triangle\Pi(\beta) \equiv \Pi(\beta,\bar{\theta}) - \Pi(\beta,\underline{\theta})$. It readily follows from (7)-(8), and (5) (and the normalization that $\underline{\theta} + \overline{\theta} = 1$) that

$$\begin{aligned}
\triangle\Pi(\beta) &= \frac{1}{2}(b-\lambda)\triangle\theta - \frac{1}{2}\lambda\left\{(1-\beta) + \lambda(1-\frac{\beta}{2})\right\}\triangle\theta \qquad \text{for } 1 \geq \beta \geq \beta_1. &(10)\\
&= \frac{1}{2}(b-\lambda)\triangle\theta - \frac{1}{2}(1+\lambda\underline{\theta})\left\{\frac{\beta}{2} - \lambda(1-\frac{\beta}{2})\underline{\theta}\right\} \qquad \text{for } \beta_1 \geq \beta \geq \beta_0. &(11)\\
&= \frac{1}{2}(b-\lambda)\triangle\theta \qquad \text{for } \beta_0 \geq \beta \geq 0. &(12)
\end{aligned}$$

If $b \leq \lambda$, low types would be preferred since $\triangle\Pi(\beta) < 0$ for all β. So let us focus on the case where $b > \lambda$. From (10)-(12), we know that $\triangle\Pi(\beta)$ is constant for $[0, \beta_0]$, decreasing in β for $[\beta_0, \beta_1]$ and increasing in β for $[\beta_1, 1]$. Given that $\triangle\Pi(\beta)$ is continuous it therefore directly follows that $\triangle\Pi(\beta)$ attains its minimum value at $\beta = \beta_1$. For the same reason, for $\beta \in [\beta_0, 1]$, $\triangle\Pi(\beta)$ reaches a maximum value at $\beta = 1$. This implies that the necessary and sufficient condition for $\triangle\Pi(\beta) < 0$ for *some* $\beta \in [0,1]$ is $\triangle\Pi(\beta_1) < 0$. Now $\triangle\Pi(\beta_1) = \frac{1}{2}\left[(b-\lambda) - \lambda\frac{1+\lambda\underline{\theta}}{1+\lambda\overline{\theta}}\right]\triangle\theta = \frac{1}{2}(b - \overline{b})\triangle\theta$. Therefore, if $b \geq \overline{b}$, then $\triangle\Pi(\beta) \geq 0$ for all $\beta \in [0,1]$ and so a high type vendor will be preferred for all order levels. This case is depicted in Figure 3(a).

If $b \in [\lambda, \overline{b})$ there will be an interval $[\beta_2, \beta_3]$ where $\beta_2 \in (\beta_0, \beta_1)$ and $\beta_3 \in (\beta_1, 1]$ where low type vendors would be preferred. A necessary and sufficient condition for $\triangle\Pi(\beta) > 0$ for some $\beta \in [\beta_0, 1]$ is $\triangle\Pi(1) = \frac{\triangle\theta}{2}\{(b-\lambda) - \frac{1}{2}\lambda^2\}$. It is straightforward to check that $\frac{1}{2}\lambda^2 < \lambda\frac{1+\lambda\underline{\theta}}{1+\lambda\overline{\theta}}$. This means there is a critical value $b' \equiv \lambda + \frac{1}{2}\lambda^2$ which is less than $\bar{b}$ but higher than λ . If $b \in [b', \overline{b}]$ then a high type vendor would be preferred for $\beta = 1$.In this case $\beta_2 \in (\beta_0, \beta_1)$ and $\beta_3 \in (\beta_1, 1)$. This case is depicted in Figure 3(b). If $b \in [\lambda, b')$ then a low type vendor would be preferred for $\beta = 1$. In this case $\beta_2 \in (\beta_0, \beta_1)$ but $\beta_3 = 1$. This case is depicted in Figure 3(c). **QED.**

Proof of Proposition 8: If a high type vendor is the first-preference vendor, his investment level is $\frac{1}{2} - \frac{1}{2}\lambda\bar{\theta}$, and if the second-preference vendor is a low type vendor then his investment level is $\frac{\alpha}{2} - (1-\frac{\alpha}{2})\lambda\underline{\theta}$. The difference between the two investment levels is:

$$\frac{1-\alpha}{2} - \lambda\left\{\frac{1}{2}\bar{\theta} - (1-\frac{\alpha}{2})\underline{\theta}\right\} = \frac{1-\alpha}{2} - \lambda\left(\frac{1}{2}\triangle\theta - \frac{1-\alpha}{2}\underline{\theta}\right).$$

So long as $\bar{\theta}$ is high enough relative to $\underline{\theta}$ this expression is negative. For instance, if $\bar{\theta} = 1$ and $\underline{\theta} = 0$, the condition for this expression to be negative is $\frac{1}{2}(1-\alpha-\lambda) < 0$ which is possible given our assumptions on the range of values of the parameters λ and α. **QED.**

Table 1. Summary Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Vendor Characteristics:					
Vendor Specificity (%)	18	43	43	0	100
Vendor Age (in 1995)	18	15	7	3	34
Vendor Size (Number of employees)	19	72	128	4	550
Distance to MTL (km)	19	334	548	7	1400
City (1=Karachi)	19	0.21	0.42	0	1
Part Order data:					
Annual Average Part price (P) [1]	273	243	741	0.2	4188
Log Annual Part Price	273	3.30	2.20	-1.61	8.34
Quarterly Vendor Scheduled Quantity (Q_S) [2]	758	2350	3750	0	31500
Quarterly Total Scheduled Quantity (TQ_S)	907	4601	6723	0	53100
Quarterly Vendor Received Quantity (Q_R)	790	3186	5383	0	81242
Quarterly Total Received Quantity (TQ_R)	907	6161	9580	0	117026
Log Quarterly Vendor Scheduled Q	558	7.55	0.96	4.61	10.36
Log Quarterly Total Scheduled Q	740	8.19	0.92	5.30	10.88
Log Quarterly Vendor Received Q	628	7.69	1.13	1.61	11.31
Log Quarterly Total Received Q	819	8.28	1.04	5.01	11.67
Quarterly Vendor Scheduled Q – Quarterly Vendor Received Q	802	-399	4253	-24,888	25,812
Undersupply	390	1569	3347	0	25812
Oversupply	449	2231	3914	0	24888
Vendor Scheduled Q Coefficient of Variation	56	0.99	0.38	0.49	2
Log Cost (log C) [3]	64	4.53	1.43	2.15	8.37
Proportion of Rejections (R) [4]	411	.01	.027	0	.29

Sources: Lahore University of Management Sciences (LUMS) survey 1997, Millat Tractors Limited (MTL) database.

Variable Descriptions:
P= Agreed contract price for a given vendor and contract year; C= MTL engineer's estimate of cost of production of a particular part for a given vendor in a given year; Q_S= Quantity scheduled from the vendor during a quarter; Q_R= Quantity received from the vendor during a quarter; TQs= Total quantity scheduled for a given part from all MTL vendors (including those not in our sample) during a quarter; TQ_R= Total quantity received for a given part from all MTL vendors (including those not in our sample) during a quarter; Undersupply/OverSupply = non-negative/non-positive values of scheduled quantity minus received quantity for a vendor. R= Fraction of the vendor's quarterly received quantity that is rejected by the MTL quality inspection section; Age= Vendor age; Specificity= The percentage of the vendor's physical assets/equipment that would become idle (i.e. would have to be scrapped) if MTL stopped buying from it; Size= Size of the vendor's labor force (in 1995); Distance= Distance of the vendor (km) from MTL; City= A dummy variable that equals 1 if the vendor is located in Karachi and 0 if in Lahore.

[1] All annual data refers to the calendar year (as opposed to fiscal) year.

[2] The price and quantity data have different number of observations since they come from different MTL sources. The former comes from the Order Information Database and the latter from the Schedule-Receipts Database.

[3] The cost data comes from a smaller data-set which had internal "cost" estimates made my MTL engineers. These estimates are not accounting costs but also include a standard markup.

[4] The rejections data is only available for the years 2000 and 2001. Proportion of rejections is defined as the number of rejected parts divided by the total number of parts supplied and is defined per quarter.

Table 2: Determinants of log Cost Estimate

	(1)	(2)
Specificity	-0.0010***	-0.0016***
	(0.0002)	(0.0001)
Age	-0.0038**	-0.0035***
	(0.0012)	(0.0010)
Size	-0.0004	-0.0004**
	(0.0003)	(0.0002)
Distance [5]		0.0022**
		(0.0008)
City		0.0841***
		(0.0177)
Fixed Effects	Part***	Part***
	Year***	Year***
Observations	61	61
R-squared	0.9980	0.9980

Table 3. Determinants of Scheduled Quantity Coefficient of Variation

Variables	(1)	(2)
Specificity	0.0017*	0.0013
	(0.0008)	(0.0026)
Age	-0.0118	-0.0149
	(0.0160)	(0.0118)
Size	0.0015	0.0046*
	(0.0029)	(0.0025)
Distance		0.0122***
		(0.0039)
City		0.1835
		(0.2090)
Fixed Effects	Part	Part
Observations	55	55
R-squared	0.91	0.94

Robust Standard errors in parentheses
Errors clustered at the vendor level
***Significantly different from zero at 1%
**Significantly different from zero at 5%
* Significantly different from zero at 10%

Table 2 is run on the smaller data-set that includes annual internal "cost" estimates made my MTL engineers. The dependent variable is logarithm of this cost estimate. Table 3 uses the quarterly scheduled quantity data but collapses the time dimension to obtain a coefficient of variation of quantity scheduled for each vendor for a specific part (the dependent variable).

[5] In all tables, the variable Distance is set equal to 0 if the vendor is in Karachi since there is no variation in distance for Karachi vendors. Thus together with the City dummy (=1 if vendor in Karachi), Distance should henceforth be interpreted as the Distance of non-Karachi vendors (i.e. "local distance").

Table 4. Determinants of log Scheduled Quantity – Total Schedule Elasticity

Variables	(1)	(2)
Specificity	-0.0094**	-0.0111**
	(0.0031)	(0.0038)
Log Total Scheduled Q	0.7337***	0.7392***
	(0.0340)	(0.0329)
Log Total Scheduled Q*Specificity	0.0010**	0.0009**
	(0.0003)	(0.0003)
LogAge	0.1688	0.0990
	(0.1029)	(0.1191)
LogSize	0.0470	-0.0173
	(0.0352)	(0.0217)
LogDistance		-0.3086***
		(0.0353)
City		-0.5723***
		(0.1555)
Fixed Effects	Part***	Part***
	Quarter ***	Quarter ***
Observations	558	558
R-squared	0.90	0.91

Table 5. Determinants of log Scheduled Quantity

Variables	(1)	(2)
Specificity	-0.0013**	-0.0034
	(0.0006)	(0.0019)
Log Total Scheduled Q	0.7619***	0.7661***
	(0.0284)	(0.0281)
LogAge	0.2125**	0.1409
	(0.0951)	(0.1150)
LogSize	0.0658	0.0002
	(0.0386)	(0.0257)
LogDistance		-0.3142***
		(0.0379)
City		-0.5891***
		(0.1595)
Fixed Effects	Part***	Part***
	Quarter ***	Quarter ***
Observations	558	558
R-squared	0.90	0.91

Robust Standard errors in parentheses
Errors clustered at the vendor level
***Significantly different from zero at 1%
**Significantly different from zero at 5%
* Significantly different from zero at 10%

Tables 4-5 use the quarterly vendor and total quantity scheduled data for each vendor and part. Table 5 runs the same specification as in Table 4 but without the extra specificity interaction term.

Table 6. Determinants of Average Log Annual Price

Variables	(1)	(2)
Specificity	-0.0007***	-0.0018***
	(0.0001)	(0.0006)
Age	-0.0071*	-0.0086**
	(0.0037)	(0.0034)
Size	-0.0003	-0.0005
	(0.0008)	(0.0009)
Distance		0.0002
		(0.0010)
City		0.0988*
		(0.0501)
Fixed Effects	Part***	Part***
	Year***	Year***
Observations	273	273
R-squared	0.99	0.99

Table 7. Determinants of Proportion of Rejections

Variables	(1)	(2)
Specificity	0.00002	0.00011
	(0.00001)	(0.00002)***
Size	-0.00008	-0.00003
	(0.00002)***	(0.00001)**
Age	0.00139	0.00152
	(0.00020)***	(0.00023)***
Distance		0.00049
		(0.00032)
City		-0.00292
		(0.00239)
Fixed Effects	Part***	Part***
	Quarter	Quarter
Observations	397	397
R-squared	0.39	0.39

Robust Standard errors in parentheses
Errors clustered at the vendor level
***Significantly different from zero at 1%
**Significantly different from zero at 5%
* Significantly different from zero at 10%

Table 6 uses annual data for the negotiated price for a given part and vendor. Table 7 uses quarterly data available quantity rejected from each vendor by part for the years 2001 and 2002.

Table 8. Determinants of log Received Quantity – Own Schedule Elasticity

Variables	(1)	(2)
Specificity	0.0124**	0.0025
	(0.0052)	(0.0034)
Log Scheduled Q	0.4434***	0.4744***
	(0.0918)	(0.1074)
Log Scheduled Q*Specificity	-0.0017**	-0.0020***
	(0.0006)	(0.0005)
LogAge	-0.1447	-0.4060***
	(0.2033)	(0.1217)
LogSize	0.1523*	0.0509
	(0.0706)	(0.0507)
LogDistance		0.2452
		(0.1527)
City		1.7908***
		(0.3505)
Fixed Effects	Part***	Part***
	Quarter***	Quarter***
Observations	479	479
R-squared	0.85	0.86

Table 9. Determinants of log Received Quantity – Total Schedule Elasticity

Variables	(1)	(2)
Specificity	0.0155***	0.0122
	(0.0033)	(0.0072)
Log Total Scheduled Q	0.2931***	0.2892***
	(0.0917)	(0.0869)
Log Total Scheduled Q*Specificity	-0.0022***	-0.0019***
	(0.0004)	(0.0005)
LogAge	0.4068	0.4430
	(0.2633)	(0.4927)
LogSize	0.2703**	0.3773
	(0.1112)	(0.2441)
LogDistance		1.1016
		(0.7236)
City		2.8665**
		(0.9397)
Fixed Effects	Part***	Part***
	Quarter***	Quarter***
Observations	518	518
R-squared	0.78	0.79

Robust Standard errors in parentheses
Errors clustered at the vendor level
***Significantly different from zero at 1%
**Significantly different from zero at 5%
* Significantly different from zero at 10%

Tables 8-9 use quarterly quantity received data for each vendor and part. The dependent variable is the logarithm of quarterly quantity received. The observations differ slightly due to missing vendor-part scheduled quantity data.

Table 10. Determinants of Undersupply
(Sample Restricted to Non-Negative values of Undersupplying)

Variables	(1)	(2)
Specificity	3.9253***	8.9634***
	(0.7187)	(1.8757)
Age	33.6682***	37.4110***
	(8.2361)	(9.2523)
Size	5.5829	9.3591**
	(3.3875)	(3.2054)
Distance		13.2401*
		(6.5339)
City		-17512.3531*
		(8489.4411)
Fixed Effects	Part***	Part***
	Quarter***	Quarter***
Observations	378	378
R-squared	0.63	0.63

Table 11. Determinants of Oversupply
(Sample Restricted to Non-Negative values of Oversupplying)

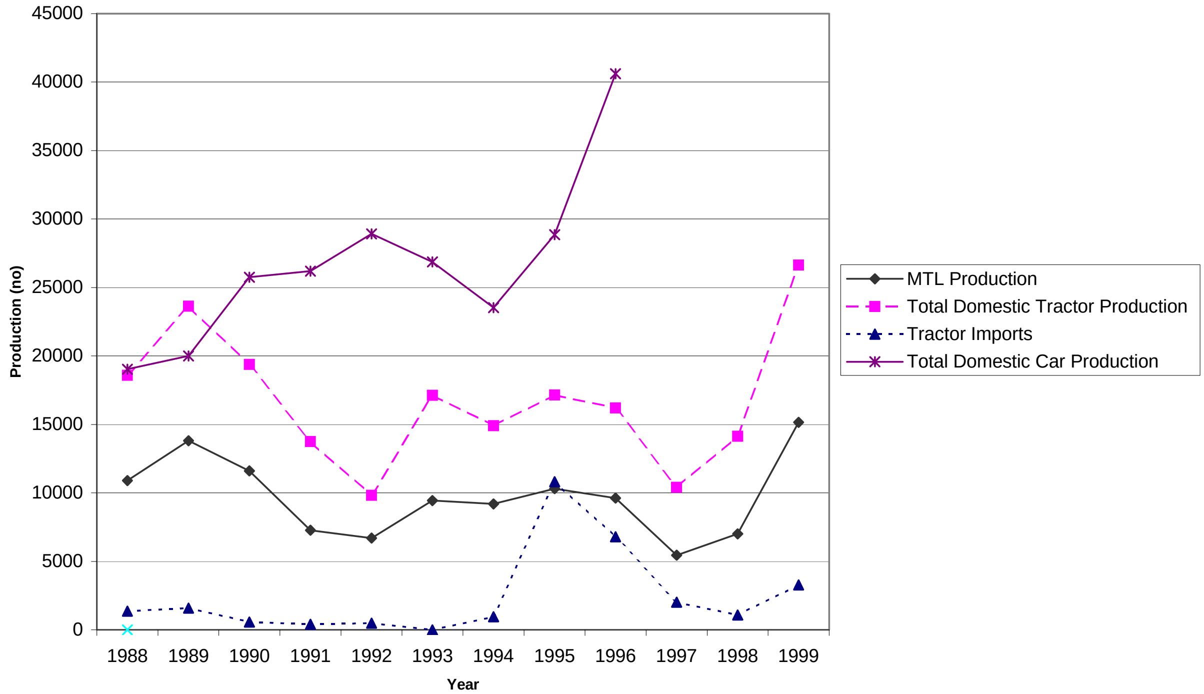
Variables	(1)	(2)
Specificity	5.8274***	-7.1748
	(1.6637)	(6.1840)
Age	-47.9560	-63.3999**
	(31.2845)	(22.0871)
Size	6.4638	0.9490
	(5.8287)	(6.4147)
Distance		-18.5537
		(21.7324)
City		25090.6336
		(28211.0151)
Fixed Effects	Part***	Part***
	Quarter***	Quarter***
Observations	443	443
R-squared	0.60	0.60

Robust standard errors in parentheses
Errors clustered at the vendor level
***Significantly different from zero at 1%
**Significantly different from zero at 5%
* Significantly different from zero at 10%

Tables 10-11 use the quarterly quantity data. The LHS variable in Table 10 is quarterly vendor scheduled quantity less quarterly vendor received quantity for cases where the former is greater or equal to the latter. Thus a positive coefficient on Specificity means that Tied vendors tend to under-supply. The LHS variable in Table 11 is the absolute value of quarterly vendor scheduled quantity less quarterly vendor received quantity for cases where the former is less than or equal to the latter. Thus a positive coefficient on Specificity means that Tied vendors tend to over-supply.

<u>**Figure 1 : Pakistan Tractor and Automobile Industry**</u>

Source: Economic Survey of Pakistan,2000
Govt. of Pakistan, Ministry of Finance, Islamabad.
MTL. Annual Reports



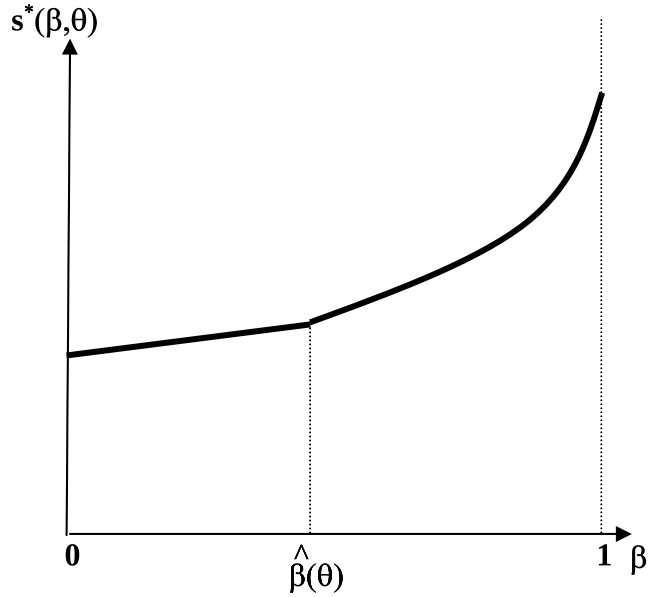


Figure 2

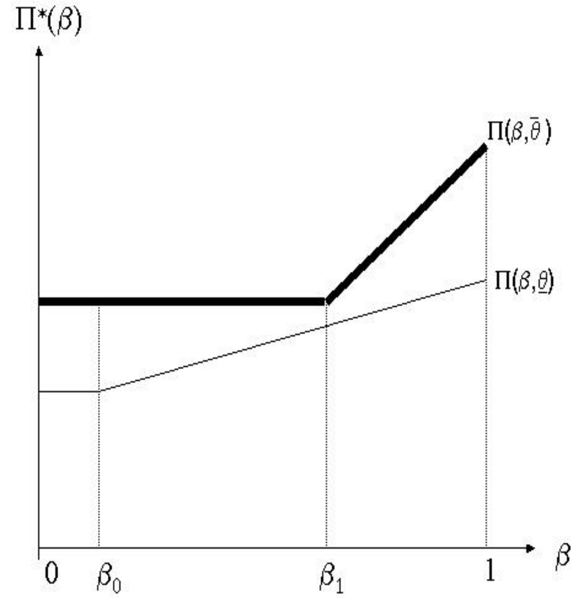


Figure 3 (a)

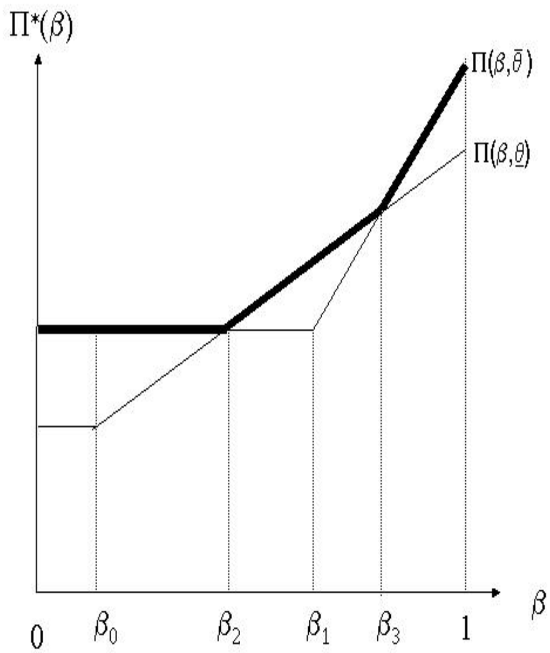


Figure 3 (b)

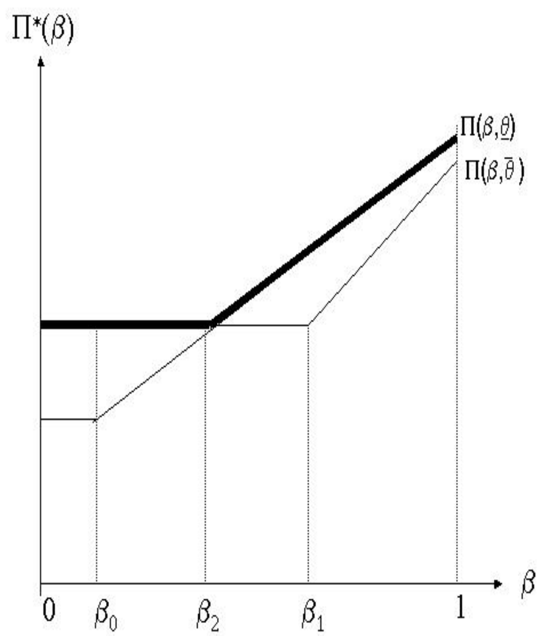


Figure 3 (c)