AVOIDABLE COST STRUCTURES AND COMPETITIVE MARKET INSTITUTIONS

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Relatively simple, avoidable cost structures can undermine the trading efficiency of otherwise efficient competitive market institutions. The continuous double auction, often considered an empirical benchmark (e.g., Friedman and Rust, 1992), exhibits "efficiency roller coasters" in avoidable cost structures. Those same structures are problematic even for market institutions that are designed to eliminate, or at least alleviate, market inefficiency (Van Boening and Wilcox, 1997; Durham et al., 1996). Other research involving "lumpy" or non-convex cost structures indicates that market institutions are generally more efficient that non-market mechanisms (Ledyard, Porter, and Wessen, 1998), and that the relative performance of market institutions may depend on both supply and demand conditions (Ledyard, Porter, and Rangel, 1997). Non-convex cost structures appear to pose a significant challenge for institutional design, and experimental data can be useful in meeting this challenge (e.g., Plott, 1997). This paper summarizes results from some competitive experimental markets with a simple avoidable cost structure.

1. A Simple Avoidable Cost Structure

Avoidable costs (Telser, 1978) are not fixed costs. While fixed costs cannot be avoided by shutting down a plant, an existing plant sometimes has a minimum positive output level and substantial variable cost associated with producing at that level. As this cost can be avoided by foregoing production, it is called a plant's avoidable cost. One example is the recurring maintenance cost of shutting down and then bringing back on line electricity generators; they are sometimes "mothballed" to avoid this cost. Another example is airline flight costs, as the bulk of variable costs are those required to fly the aircraft, and the marginal cost of passengers and freight typically account for a small portion of total variable cost.

Figure 1 shows avoidable cost structures in two experimental market environments. There are four sellers, and each has an avoidable cost and a capacity constraint. A seller does not incur her avoidable cost if she does not sell any units, but if she sells as many as one unit, she incurs the avoidable cost. As there are no marginal costs, a seller's total production cost equals her avoidable cost, regardless of whether she sells one unit or her entire capacity. A seller's average cost at capacity is her avoidable cost divided by her capacity. For example, Figure 1 shows Seller 1 with an eight-unit capacity and an avoidable cost of 960, so her average cost at capacity is $960 \div 8 = 120$. At any price

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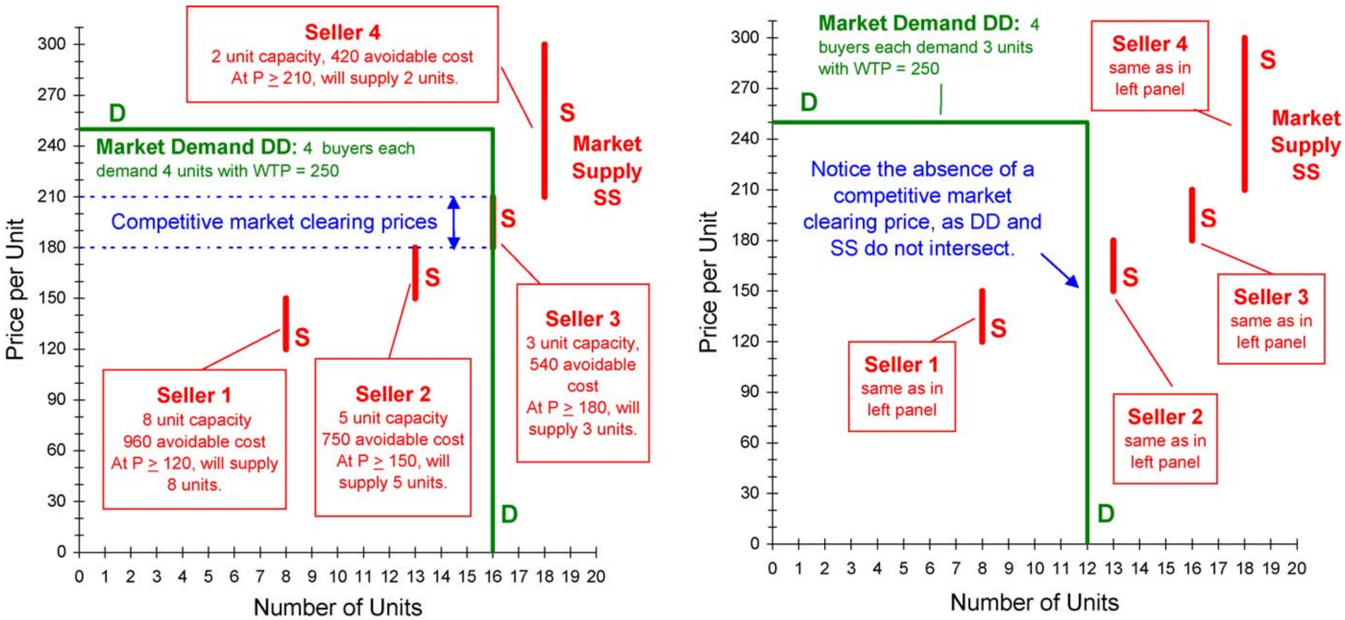

Figure 1. Experimental market environments with avoidable cost structures. Left panel: Observe that when the 4 buyers demand 4 units each, any price in the open interval (180, 210) is a competitive market clearing price, and the maximum demand of 16 units exactly exhausts the capacity of the three most efficient sellers (Sellers 1, 2 and 3). Right panel: Observe that when the 4 buyers demand only 3 units each, there is no competitive market clearing price, and the maximum demand of 12 units does not exhaust the capacity of the two most efficient sellers (Sellers 1 and 2).

greater than or equal to 120, she will provide all eight of her units to the market, and at any price below 120, she will provide zero units to the market. Similarly, at any price at or above 150, Seller 2 will provide five units to the market. Seller 3's average cost at capacity is 180 (three unit capacity, 540 avoidable cost), and Seller 4's is 210 (two unit capacity, 420 avoidable cost).

In Figure 1, the market supply curve SS is a series of spikes at each seller's average cost at capacity. At any price below 120, none of the four sellers will supply units to the market. At any price between 120 and 150, Seller 1 will enter the market and supply her eight units, but none of the other three sellers will supply units. Thus the market supply curve is horizontal from 120 to 150, above eight units. At a price between 150 and 180, market supply is thirteen units: Sellers 1 and 2 will supply eight and five units, respectively, while Sellers 3 and 4 each supply zero units. Seller 3 will add her three units to market supply at any price above 180, and Seller 4 will enter the market with her two units at any price above 210.

In the market environments shown in Figure 1, there are four buyers with a demand capacity of either four units each (left panel) or three units each (right panel). All four buyers have a maximum willingness to pay, or WTP of 250 for any one unit. Thus the market demand curve DD is horizontal at 250 until maximum demand is reached, and then it drops vertically to the axis. In the left panel, the maximum demand is 16 units, as each of the four buyers has a demand capacity of four units. In the right panel, each of the four buyers demands at most three units, so maximum demand is 12 units.

In the left panel of Figure 1, market demand and supply intersect on the open interval (180, 210), so any price in that range is a competitive market clearing price, and the maximum demand exactly exhausts the capacity of the three most efficient sellers (Sellers 1, 2 and 3). In the right panel, each of four buyers has a three-unit demand capacity, so the maximum demand is only 12 units. Note the absence of a competitive market clearing price or prices, as the market demand and supply curves do not intersect. Also note that the maximum demand (12 units) does not exhaust the capacity output of the two efficient sellers (Sellers 1 and 2, total capacity of 13 units).

2. Three Market Institutions

The multiple unit double auction, or MUDA (Plott, 1991), is an electronic double auction. Buyers and sellers bargain multilaterally and publicly over contract prices, with buyers making bids and sellers making asks sequentially as they wish. The highest (or standing) bid and lowest (or standing) ask are instantaneously updated and displayed to the entire market via private computer screens. Binding contracts occur when any buyer accepts the standing ask or when any seller accepts the standing bid. One important feature of MUDA is that a buyer (seller) who accepts an ask (bid) can purchase (sell) any or all of the units offered at that ask (bid). That is, bids and asks can be for multiple or "blocks" of units at a given per-unit bid/ask price, but agents are not obliged to accept all the units in a multiple unit bid/ask. For instance, a buyer may accept just one unit of a three-unit block offered by some seller.

The bundled unit double auction, or BUDA (Van Boening and Wilcox, 1997), is a variation of MUDA that allows all-or-none bids, asks and contracts for 1-, 2- or 3-unit bundles. For example, if a buyer accepts a 2-unit ask, he is obliged to purchase both units at the given per-unit ask price. Additionally, in the "restricted BUDA" or RBUDA, 1-unit trading is not allowed, so that all bid, ask and contract activity is for 2-unit and 3-unit blocks. In the avoidable cost structure shown in the right panel of Figure 1, theoretically efficient outcomes require non-linear prices and that no 1-unit trades occur (Van Boening and Wilcox, 1997). BUDA and RBUDA were designed to promote nonl-inear prices, and so they should be more efficient institutions than MUDA, as the double auction has a stylized tendency towards "the law of one price." And RBUDA should be more efficient than BUDA, as RBUDA explicitly prohibits the 1-unit trades that are ruled out by theory.

The Smart Market (Durham et al., 1996) is a version of the posted-offer market in which each seller submits a two-part price: a fixed vendor's fee, which must be paid before any units can be sold, and a per-unit price and a corresponding quantity. Automated buyers are programmed to reveal demand. A smart-market computing center then maximizes total surplus subject to the price, quantity and vendor fee constraints. Sellers can protect themselves from losses by simply by charging their avoidable cost as their vendor fee. Additionally, if each seller offers her capacity and the per-unit prices do not exceed the buyers' value, the Smart Market will choose the most efficient sellers and demand will be exhausted. Thus this institution is expected to consistently achieve (near) 100% efficiency.

3. The Results

Figure 2 compares the per-period trading efficiency of a standard marginal cost structure to the two avoidable cost structures under double auction (MUDA) trading (see Van Boening and Wilcox, 1996). Trading efficiency is defined in the usual manner, as total trading profit across all buyers and sellers divided by the maximum possible gains from trade. In Figure 2, just over 80% of the trading periods in the marginal cost structure are 90–100% efficient. This contrasts sharply with both of the avoidable cost structures, where less than half of the trading periods are 90–100% efficient (relative frequency 0.44 with a competitive market clearing equilibrium, 0.35 without a competitive equilibrium). In fact, when there is no competitive equilibrium, efficiency is as likely to be less than 70% as it is to be 90–100%: 37% ($= 0.27 + 0.10$) of the trading periods are less than 70% efficient, and 35% of the trading periods are 90–100% efficient.

Figure 3 shows per-period trading efficiency data for MUDA, BUDA, RBUDA and the Smart Market in the avoidable cost structure with no competitive equilibrium (summarized from Van Boening and Wilcox, 1997; Durham et al., 1996). Recall that BUDA,

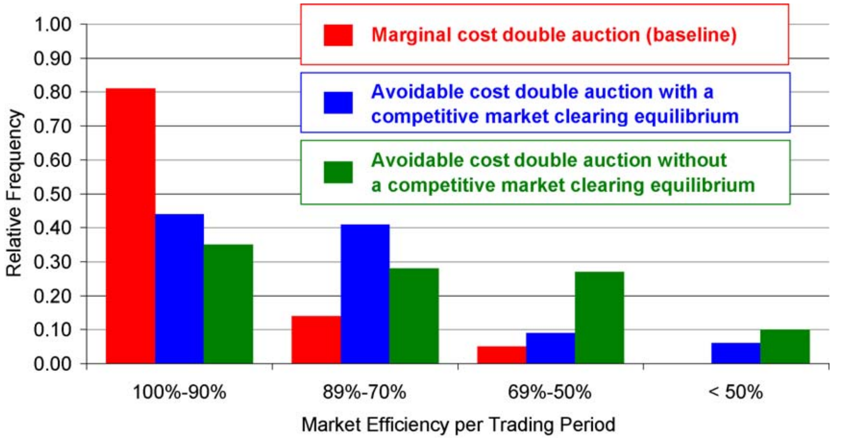

Figure 2. Per-period trading efficiency in marginal cost and avoidable cost structures. Observe that: (a) In the marginal cost baseline, just over 80% of the trading periods are 100–90% efficient, but in the avoidable cost double auctions, less than 50% of the trading periods are 100–90% efficient (relative frequencies of 0.44 and 0.35). (b) In the absence of a competitive equilibrium, the trading efficiency in avoidable cost double auctions is equally likely to be less than 70% (relative frequency of $0.27 + 0.10 = 0.37$) as it is to be 90% or more (relative frequency of 0.35).

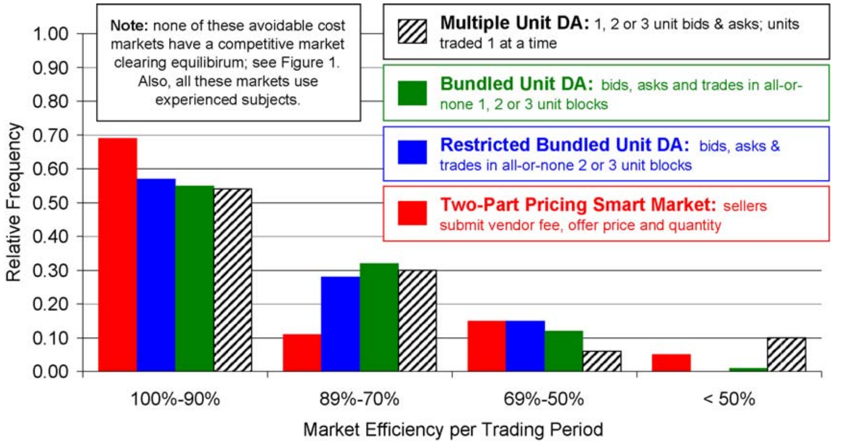

Figure 3. Per-period trading efficiency in four different institutions with avoidable cost structures. Observe that the new institutions (BUDA, RBUDA and Smart Market) each have a greater frequency of trading periods in the 100–90% interval than does the standard double auction (MUDA), but (a) all four institutions have a frequency less than 0.70 in this interval, which is unusual for experienced subjects, and (b) the greatest difference is only 15% (0.54 for MUDA, 0.69 for Smart Market). Also observe that in all four institutions, well over 10% of the trading periods have efficiency less than 70%. This is also unusual for experienced subjects.

RBUDA and the Smart Market were specifically designed to facilitate efficient outcomes efficiency in avoidable cost structures. The trading efficiencies for all four institutions are relatively low, at least compared to what one would expect in a comparable marginal cost structure with experienced subjects. Relative to the double auction, the two-part pricing Smart Market does increase the frequency of trading periods that are 90–100% efficient (relative frequencies of 0.54 for MUDA, 0.69 for Smart Market), but even in the Smart Market almost a third of the trading periods are less than 90% efficient. BUDA and RBUDA only marginally improve trading efficiency relative to MUDA. On a positive note, BUDA, RBUDA and the Smart Market all have a lower frequency of trading periods in the "<50% efficient" range than does MUDA. However, in all four institutions over 10% of the trading periods are less than 70% efficient, even though all of the markets summarized in Figure 3 used twice or three times experienced subjects. The failure to consistently achieve high trading efficiency is perplexing.

4. A Next Step: Cooperative Arrangements?

The search continues for a competitive institution that will consistently yield high trading efficiency in these avoidable cost structures. But frequently, such institutions have a uniform pricing tendency that cannot implement surplus shares that are in the core of the underlying cooperative game (Van Boening and Wilcox, 1996). This suggests that cooperative arrangements that allow for greater transfer flexibility might also implement stable, efficient outcomes, particularly when no competitive equilibrium exits (Telser, 1988). Archibald, Van Boening, and Wilcox (2002) allow experienced subjects to make explicit arrangements as to per-unit prices, output quantity and division of aggregate seller profit (i.e., side payments) in avoidable cost markets. In one of three different experimental protocols, efficient outcomes were consistently observed. However, under the other two protocols, collusion often resulted in inefficient production. Given the sensitivity of those results to changes in protocol, cooperative market institutions also remain an area of fruitful research.

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