Forward Aggregation in Electronic B2B Markets: Model and Experimental Findings

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Abstract: This paper studies the feasibility of creating a central supplier-driven Business-to-Business (B2B) exchange, also known in industry parlance as Forward Aggregation, in lieu of a collection of bilateral supplier-buyer markets. We employ a game theoretic model of suppliers and buyers and corroborate our results through experiments. A central result that emerges from our analysis is that heterogeneity in buyer valuations does *not* produce any gains to suppliers from aggregating buyers and creating a pooled demand. Specifically, we show that when the forward aggregator chooses to deploy an auction-based price discovery mechanism, the resulting profits from a centralized auction market, even one that allows the suppliers to collude on quantities supplied, are dominated by the revenues from the Decentralized market. We corroborate and sharpen our insights using auction markets in experimental settings. We find strong empirical support for the theoretical findings. We demonstrate via experiments that the actual *Revenue Deficit* – the difference between predicted and actual revenues that accrue to suppliers – is even greater than the theoretically predicted revenue losses from aggregation. Our research sheds light on the nature and extent of barriers to supplier participation in B2B exchanges.

Keywords: *B2B, Exchanges, Aggregation, Electronic Markets.*

1 Introduction

Electronic exchanges that facilitate trade between businesses (Business-to-Business or 'B2B' exchanges, in industry parlance) in *direct-engineered goods and commodities* attracted considerable venture capitalist funding in the past few years. The phenomenon quickly gained the interest of practitioners, businesses and analysts and as a consequence the business press accorded it considerable coverage. The rather quick rise to prominence of these exchanges and their sometimes quick fall from grace has been the subject of many discourses in the business press and several trade publications. Analysts have tried to dissect why some of these exchanges failed to gain liquidity, and identify the locus of future opportunities in this business space [Schwartz, M. 2001]. Nevertheless, a variety of issues surrounding the logic, functioning and effectiveness of these exchanges are not well-understood, and rigorous research spotlighting these issues is urgently needed.

The Operations academe has seen a spate of recent research on the different possible contracts between players in a supply chain and their effects on individual and social surpluses (On these matters, the reader is referred to the fine survey in [Cachon 2003]). Yet, little has been written on the effect of exchanges (specifically, consortia of buyers and / or suppliers) in altering the industry structure, and hence, on their effect on buyer and supplier profits, supply chain efficiencies and welfare. This paper attempts to bridge that gap, by incorporating heterogeneous buyer valuations in the modeling of supplier-driven consortia for the trading of physical products in a B2B context.

The factors that drive market outcomes in B2B exchanges tend to be numerous and complex. The asymmetry of power between suppliers and buyers caused by excessive fragmentation of one of the two parties, the extent of demand (supply) uncertainty faced by suppliers (buyers), the exchange's choice of revenue model, the nature of the price discovery mechanism (such as auctions, fixed prices, volume discounting, RFQs and negotiated prices), and the cost structure that buyers and suppliers face in establishing linkages between their information systems and that of the exchange are some of the many factors that can affect the viability of the B2B exchange [Goldbaum 1999, LaMonica 2001]. In this context we review the state of Praxis and identify some of the key factors that determine the efficiency of electronic B2B exchanges and the gains that accrue to buyers and suppliers.

1.1 B2B Markets: A Review Of Praxis:

Some reports in the trade and business press as well as research analyst reports suggest that suppliers and buyers gain under conditions of demand and supply uncertainty (respectively) when they move to a market that aggregates supply and demand [Forrester 2002, Laseter 2001]. These reports claim that when individual suppliers face demand uncertainty, the price schedules that they pick result in sub-optimal revenues. Some studies of electronic B2B aggregators suggest that a market operator that aggregates either supply or demand can bring gains to the market by lowering the volatility of supply and demand through aggregation [Kaplan 2000, Laseter 2001]. Thus, the extent of fragmentation of buyers and suppliers in a B2B market has a significant impact on its success. It seems to be widely accepted that when there is significant asymmetry in the extent of fragmentation (i.e., if one of the two sides to the transaction is less fragmented than the other), the market operator will have to configure the features of the exchange and the choice of market mechanisms in alignment with the interests of the less fragmented side-- while ensuring this is in compliance with anti-trust laws and does not verge on price-fixing [Sawhney 1999, Coburn 2002].

More recent reports however, raise several doubts about the benefits that suppliers may actually gain from joining B2B markets. A recent report by the research firm Forrester Research stated that the Chief Marketing Officers (CMOs) of B2B exchanges faced considerable challenges in getting companies (suppliers) to join these exchanges. The report inferred from a survey of B2B aggregators that these electronic markets faced significant barriers to adoption and generation of sustainable revenues [Forrester 2007a]. Another report by the same firm notes that the benefits of aggregating supply (suppliers) does not seem to be enough to drive adoption of the B2B markets by suppliers. The report points out that in order to gain traction with suppliers, aggregators have been forced to add several value-added services ranging from marketing to deep integration of inter-organizational information systems [Forrester 2007b]. Many of the early B2B market initiatives such as Chemdex and Vintro have gone out of business and others such as VerticalNet find themselves with vastly eroded market capitalization values and inadequate revenue streams. Yet others such as Covisint have been slow to take off and face uncertain revenue prospects [Knowledge@wharton 2002, Laseter 2001].

Recent research featured in the Wharton School's research journal, Knowledge@Wharton, suggests that prior to the emergence of B2B exchanges, suppliers and buyers conducted transactions through bilateral channels. However, many B2B aggregators neither expanded the market nor brought in more buyers, instead focusing on making existing transactions and buyer-suppler relationships more efficient [Knowledge@wharton 2003; Knowledge@wharton 2005]. Another research report observed that suppliers faced a trade-off between the efficiencies of an electronic aggregation mechanism that facilitates – inter alia -- effective coordination of their supply, and the increased competition that they may face as a result of moving to an aggregate market where buyers may gain some price visibility [Knowledge@wharton 2002]. A recent research report noted that several Global B2B aggregators - such as *ECeurope* in Europe, *Global Sources* and *Alibaba* in China, and *IndiaMart* in India – have arisen, that aggregate suppliers and offer a single point supply option to buyers. The reports points out that these markets are characterized by great heterogeneity in buyers and face uncertain prospects because of the trade-offs that suppliers face in joining them.

In this paper we will examine each of the factors above and investigate how they impact the market participants in equilibrium. The remainder of this paper is organized as follows. In Section 2 we review the related literature on B2B markets, aggregation, and the incentives that buyers and suppliers have to adopt trading and information sharing mechanisms. Section 3 develops a model of forward aggregation (supplier-driven consortia), and Section 4 discusses the implications of the results. Section 5 sheds further insights into forward aggregation via a number of experiments. Finally, Section 6 concludes, and provides directions for future research.

2 Literature Review

Industry-wide consortia with the objectives of lobbying the Government and policy-makers (to influence policy in favor of the industry as a whole) as well as presenting a united front to both upstream and downstream firms within the specific vertical (to facilitate collective bargaining) predate both the Internet and the World Wide

Web (WWW). Nevertheless, by dramatically lowering coordination costs, technology has led to a spurt in such industry-wide exchanges and consortia.

Lower coordination costs have also led to creative and new forms of price-discovery mechanisms other than simple list prices. Freed from the constraints of time and place, there has been a boom in electronic auctions, group-buying and other forms of dynamic pricing, enabling "customized pricing, promotion, and inventory policies in *real time*" [Elmaghraby 2003]. Another stream of recent research studies the integration of procurement contracts, options and spot markets for B2B transactions; see [Kleindorfer 2003; Wu 2005; Mendelson 2007] and references therein. Anand and Aron model group-buying as a mechanism for sellers to create the 'band-wagon' effect among buyers, by exploiting positive externalities generated by the pricing scheme and enabling buyers to coordinate among themselves through a seller-mediated online platform [Anand 2003]. Anand and Aron also demonstrate through a comprehensive survey spanning multiple continents that group-buying is being widely used for B2B commerce. Auctions have been widely used for "treasury bills and bonds, some corporate financial securities, art objects, oil leases and government contracts" [Harris 1981], well before the advent of the internet. Harris and Raviv were among the first researchers to study the value of price discrimination for a monopolist selling to customers with heterogeneous valuations, and also show how the monopolist's capacity matters [Harris 1981]. They model and study "priority pricing schemes" (which attempt to discriminate among heterogeneous customers by charging them different prices, in order to maximize the monopolist's profits) and compare their performance with simple list pricing in capacitated and uncapacitated settings. Interestingly, while priority pricing schemes (including auctions and various kinds of congestion pricing) implicitly exploit competition among potential buyers, the group-buying schemes surveyed and modeled by Anand and Aron charge the same final price to all successful buyers—relying on market-expansion through buyer cooperation (induced by positive externalities) to maximize the sellers' surplus [Harris 1981; Anand 2003]. Pinker, Seidmann and Vakrat provide a fine survey of contemporary business and research challenges relating specifically to *online* auctions [Pinker 2003].

Chopra, Dougan and Taylor provide an elegant classification scheme to facilitate the analysis of the benefits of B2B e-Commerce opportunities. They argue that B2B initiatives should be based on one of three primary motivations [Chopra 2001]. In increasing order of value-creation, but also at increasing levels of implementation difficulty, the three motivations are: *(i) Transaction efficiencies*, including electronic processes that cut down on the costs of handling proposals and quotations, processing orders, operating call centers, etc., *(ii) Market-efficiencies*, arising from easier aggregation of supply or demand, and the deployment of price-discovery mechanisms tailored for the industry, and *(iii) Supply-chain enhancements*, enabling superior information visibility and inter-firm collaboration within the supply chain vertical [Chopra 2001]. In a similar vein, Lucking-Reiley and Spulber break down the benefits from B2B e-Commerce as stemming from *(i) transaction cost efficiencies* through automation and *(ii) economic efficiencies* from intermediation, marker-making and/or the reorganization of firms and supply chains [Lucking-Reiley 2001]. Viewed through the lens of Chopra, Dougan and Taylor's classification, this paper focuses on the analysis of the effect of forward (supplier-led) aggregation on *market* efficiencies, specifically, efficient price-discovery.

Amit and Zott provide an integrative view of the value creation theories in the received entrepreneurship and strategic management literatures, and apply these to their analysis of 59 e-Businesses (defined as businesses built around the internet). They argue that e-Businesses often employ novel exchange mechanisms and transaction structures not found in traditional businesses—transaction content, structure and governance are all important sources of value [Amit 2001]. In a study of 45 B2B exchanges operating in the European Union, Ordanini finds that exchange revenues are strongly positively correlated with levying *transaction-based fees*; other revenue models such as subscriptions and advertising are much more difficult to sustain [Ordanini 2006]. Mukhopadhyay and Kekre empirically study the strategic benefits accruing to a B2B supplier from electronic linkages with their customers [Mukhopadhyay 2002].

Kaplan and Sawhney provide an alternative system of classification based on the ownership, incentive alignments (buyer or supplier consortia) and the goods bought and sold on B2B Exchanges [Kaplan 2000]. We show that under fairly general conditions of market-structure, suppliers do not have incentives to connect to a central trading platform since this serves to dilute their monopolistic pricing power. The more general problem of inducing suppliers and buyers to connect to each other via an electronic information sharing mechanism was explored by Barua and Lee, who investigate the problems of platform adoption and conclude that suppliers may have to join electronic information exchange platforms out of strategic necessity [Barua 1997]. Our research investigates the impact of an 'information rent' that is paid by suppliers to buyers through the auction mechanism that serves as an incentive for buyers to reveal their WTP (through bids). Zhu studies the effects of information transparency induced by a B2B exchange (which risks firms' data confidentiality) on firms' incentives to participate in that exchange, under different models of competition [Zhu 2004]. Dai and Kauffman investigate the tradeoffs for firms between participating in third-party markets and adopting a proprietary information-exchange mechanism such as EDI [Dai 2000]. Bakos and Brynjolfsson analyze the optimal number of suppliers that buyers would transact with, in the context of costs associated with incomplete contracts. They find that when faced with the need to make it worthwhile for suppliers to make non-contractible investments in innovation, responsiveness and information sharing, buyers will restrict the pool of competing suppliers and prefer to deepen their transactions with a small number of them [Bakos 1993].

Our paper explores the dynamics of aggregation and quantity coordination among suppliers, and compares two different pricing mechanisms. In our research, the aggregation is at the initiative of suppliers, and hence the intermediary's incentives are fully aligned with those of the suppliers. In other settings, the aggregator's incentives may differ from those of the firms being aggregated; such misalignment of incentives has been studied in the context of horizontal alliances [Nault 2001] and "Information Intermediaries" [Bhargava 2004]. We explore how a B2B market may enable suppliers to collude on quantities and not violate anti-trust measures. In the next section we formulate an analytical model of a B2B aggregator of suppliers, and derive and analyze the equilibrium.

3 A Model of Forward Aggregation

We now develop a model of Forward Aggregation (i.e., the aggregation of supply by a supplier consortium) that specifically incorporates 'superior' supplier bargaining power, when buyers are heterogeneous with respect to their valuations. As discussed previously, the bargaining power that suppliers enjoy may arise from a combination of factors such as: differential exposure to risk, buffer inventories, access to alternate demand regimes (such as markets in other countries), costly relationship-specific investments made by buyers etc.

We begin by analyzing the Decentralized Markets Regime - a collection of fragmented and non-overlapping markets defined by bilateral price contracts. Later we will analyze the impact of supplier-led aggregation of these markets on equilibrium prices and profits, and welfare.

3.1 The Decentralized Markets Regime:

The Decentralized Regime consists of several bilateral markets of buyers and suppliers where each buyer is supplied by a price-setting monopolistic supplier. We assume that there are n such markets. We assume that the supplier's production costs are linear, i.e., the cost of producing each unit of the good is a constant (without loss of generality, and consistent with previous literature [*cf* Hamilton 1994, Tirole 1990, Wilson 1989] we normalize this to zero). Each buyer demands exactly one unit of a divisible, manufactured good. For now, we will assume that buyer valuations of the good are independently drawn from a distribution $F(\cdot)$ over the bounded support set $[a,b]$ with $b \geq a > 0$, $F(a) = 0$ and $F(b) = 1$. The density $f(\cdot)$ of the distribution is well-defined over the entire support set; the *distribution* is common knowledge (and hence, known to the suppliers), while the actual valuations are the buyers' private information. We also make the widely used assumption that the distribution has an *increasing* hazard rate; as is well known, most common distributions including the Normal, Uniform, Erlang and truncated Normal distributions satisfy this property. Thus, the hazard rate function $H(x) = \frac{f(x)}{1-F(x)}$ is increasing in the interval $[a,b]$. In the Decentralized Regime, the supplier sets a price p that optimizes his revenue.

<u>Proposition 1</u>: The profit maximizing price, attendant supplier profits and the buyer surplus are given by the following expressions:

(1) <u>Profit maximizing price:</u>

$$\begin{cases} P^* \text{ is the unique solution of the equation } P^* = \frac{1-F(P^*)}{f(P^*)} = \frac{1}{H(P^*)}, \text{ if } a \cdot f(a) < 1; \\ \text{and} \\ P^* = a, \text{ otherwise;} \end{cases}$$

where the subscripts *D* and *A* denote the Decentralized and Aggregate regimes respectively.

(2) <u>Supplier profits:</u> The representative supplier's profits are given by:

$$S_D^* = P^* \cdot \left(1 - F(P^*)\right) = \left(P^*\right)^2 f(P^*).$$

(3) <u>Buyer surplus</u>:

A buyer's surplus is $(v - P^*)^+ = \max\left\{v - P^*, 0\right\}$, where v is his valuation of the good. His *expected* surplus is $B_D^* = \left[E(v \mid v > P^*) - P^*\right]\left(1 - F(P^*)\right)$. ♦

<u>Proof</u>: All proofs are provided in Technical Appendix A.

3.2 Forward Aggregation:

Now we look at the case of supplier-aggregation-- by a B2B aggregator who organizes and favors suppliers in selling to buyers via a B2B exchange. Such an aggregator who favors suppliers is occasionally a third-party firm, but most often simply an Association formed by the suppliers, which serves as a centralized clearinghouse. The suppliers will choose to employ such an aggregator only if they can improve their overall expected profits. Thus, as a first step, we need to derive the suppliers' optimal profits in the aggregate market. We model the use of auction-based price discovery in the aggregate market for several reasons. Firstly, auctions have been a popular price-discovery mechanism used in business-to-business marketplaces [Forrester 2002, Porter 2000]. Further, auctions have been widely recognized as the preferred instrument for extracting buyer values, and by extension, buyer WTP, under conditions of demand uncertainty [cf. Klemperer 2000, Riley 1981]. Additionally, the posted price mechanism as the aggregator's mechanism of choice raises questions of possible collusion between suppliers, facilitated by a centralized clearinghouse (the aggregator) that acts as a price-fixing cartel. In fact, such supplier consortia have invited the scrutiny of regulatory bodies such the FTC [Economist 2001, Sterling 2001]. Similarly, an aggregator that auctions off quantities produced by suppliers after setting a minimum price produces the same collusive outcomes for the supplier cartel, because the minimum price in the auction secures for the supplier cartel at least the same profits as the price-fixing aggregator does. For a comprehensive discussion of the structure and operation of price-fixing cartels, see Donsimoni *et al* [Donsimoni 1986].

We assume (as is common in the literature) that each winner in the auction wants (and gets) exactly one "unit". In practice, a "unit" is domain-specific—it could refer to a basket of good(s) measured in the hundreds, thousands or millions of units. Typically, the aggregate demand (i.e., set of potential buyers) far exceeds the supply, i.e., $k \ll n$, but buyers' willingness-to-pay (WTP) is heterogeneous—an ideal setting for employing a price-discovery mechanism such as an auction, which selects buyers with the highest WTP.

Suppose the auctioneer (aggregator) decides to auction off exactly *k* units ($1 \le k < n$). In general, the auctions could be run as first or second price auctions, in open or sealed-bid formats. By the Revenue Equivalence Theorem, we know that these different auctions would generate the same outcomes (winners) and identical expected revenues. Hence, without loss of generality, we focus on the second price (Vickrey) auction, which is known to be analytically tractable; our results are equally applicable to the other standard private-value auctions. Let $v_{(1)}, v_{(2)}, \cdots, v_{(n)}$, denote the rank-ordered valuations of the buyers, where $v_{(1)} \ge v_{(2)} \ge \cdots \ge v_{(n)}$. Thus, $v_{(k)}$ denotes the value placed on the good by the buyer with the k^{th} highest valuation. The following Proposition derives *(i)* the expected clearing price in the auction as a function of k, *(ii)* the optimal number of units to sell, *(iii)* the optimal supplier revenues under aggregation and *(iv)* each buyer's expected surplus.

<u>Proposition 2</u>: In an auction with *n* buyers whose valuations are drawn from the distribution $F(\cdot)$:

(i) The expected auction clearing price $P^*(k)$ where k units of a good are offered ($k < n$), is given by:

$$P^*(k) = E[v_{(k+1)}] = \int_a^b x \cdot \frac{n!}{(n-k-1)!k!} \left[F(x)\right]^{n-k-1} \left[1 - F(x)\right]^k f(x)dx .$$

(ii) The optimal quantity to be offered and sold, k^*, is given by

$$k^* = \underset{1 \le k < n}{\arg\max} \left\{ k \cdot E[v_{(k+1)}] \right\}$$

(iii) The optimal supplier revenues are $\pi_A^* = k^* \cdot P^*(k^*) = k^* \cdot E[v_{(k^*+1)}]$.

(iv) The $(k)^{th}$ buyer (where (k) is his rank ordering as discussed above) obtains an expected surplus $B^*_{A,(k)} = \begin{cases} E[v_{(k)}] - E[v_{(k^*+1)}], & \text{for } 1 \le k \le k^*; \\ 0, & \text{otherwise.} \end{cases}$ ♦

4 Comparisons

In this Section, we will compare the performance of the pre-aggregation scenario (the Decentralized Regime, analyzed in Section 3.1) and the Forward Aggregation scenario (analyzed in Section 3.2), especially from the viewpoint of the suppliers whose choice it is to operate through an aggregator. If the suppliers as a whole do not gain from the aggregation of buyers, they will prefer to operate under the Decentralized Regime. On the other hand, if they collectively register an increase in their total profits by aggregation, the aggregation is always feasible—any supplier who loses out by the aggregation can be compensated through side-payments.

The analysis in sections 3.1 and 3.2 included very general functional forms, and the results therein apply to all distributions of buyer valuations characterized by the property of monotonically increasing hazard rates. This includes many common parametric distributions such as the Normal, the Uniform and the Erlang. In order to quantify and compare outcomes (such as the number of buyers, the final price and aggregate supplier profits) under the Decentralized and Aggregation Regimes, we need to make specific parametric distributional assumptions. In what follows, we assume that buyer valuations are distributed uniformly. In Bayesian statistics, the Uniform distribution has an appealing interpretation as the "uninformed" prior—the logical choice for an auctioneer lacking any information about specific buyer valuations other than the end points of the support set. Hence the Uniform distribution has been widely used in modeling distributions of customer valuations. We therefore, specialize the distribution $F(\cdot)$ of buyer valuations to the uniform distribution $U\left[R-s, R+s\right]$, where $R \geq s > 0$, which has a mean of *R* and a variance of $\frac{s^2}{3}$. Observe that the coefficient of variation is the ratio of the standard deviation to the mean, which is given by $\frac{s}{\sqrt{3}R}$. Therefore, the reciprocal ratio $\frac{R}{s}$ is a measure of the inverse of the coefficient of variation. We term this ratio the *Value Concentration Ratio*. The mean of the interval, *R* , is a measure of how much buyers (on average) value one unit of the good apiece, while *s* is a measure of the extent of the dispersion of buyer valuations around *R*. The measure that we define, the *Value Concentration Ratio,* therefore reflects both these aspects – i.e. value and the extent of dispersion around the mean buyer valuation. We find that this is a key ratio that drives many of the quantifiable results that follow.

Propositions 3 and 4 below derive the optimal solutions and profits for each of the two cases – pre-aggregation (decentralized markets) and aggregation, for the above (parameterized) distribution of buyer valuations. They are obtained by specializing the previous Section's Propositions 1 and 2 respectively to the parameters of this distribution.

<u>Proposition 3 [Decentralized Markets]</u>: The profit maximizing price, attendant supplier profits and expected buyer surplus depend on the Value Concentration Ratio $\frac{R}{s}$, and are as follows:

<u>Case *(i)*:</u> $\frac{R}{s} \leq 3$

$$P^* = \frac{R+s}{2}; S_D^* = \frac{(R+s)^2}{8s} \text{ and } B_D^* = \frac{(R+s)^2}{16s}. \tag{4.1}$$

<u>Case *(ii)*:</u> $\frac{R}{s} > 3$

$P^* = R - s;\ S_D^* = R - s$ and $B_D^* = s$. ♦

<u>Proposition 4 [Aggregation]</u>: In an auction with *n* buyers whose valuations are drawn from a uniform distribution $\left[R-s, R+s\right]$,

(i) The expected auction clearing price $P^*(k)$ where k units of a good are offered ($k < n$), is given by: $P^*(k) = E[v_{(k+1)}] = (R-s) + 2s \cdot \frac{(n-k)}{(n+1)}$.

(ii) The optimal quantity to be offered and sold is given by

$$k^* = \begin{cases} \frac{R(n+1)+s(n-1)}{4s}, \text{ if } \frac{R}{s} < \frac{3n-5}{n+1}; \\ n-1, \text{ otherwise.} \end{cases} \tag{4.2}$$

(iii) Expected price when the optimal quantity is offered, is:

$$\mathrm{P}^*\left(k^*\right) = \begin{cases} \frac{R(n+1)+s(n-1)}{2(n+1)}, \text{ if } \frac{R}{s} < \frac{3n-5}{n+1}; \\ R - \frac{n-1}{n+1} \cdot s, \text{ otherwise.} \end{cases} \tag{4.3}$$

(iv) The expected supplier revenues when the optimal quantity is offered are

$$\pi_A^* = \begin{cases} \dfrac{\left[R(n+1)+s(n-1)\right]^2}{8(n+1)s}, \text{ if } \dfrac{R}{s} < \dfrac{3n-5}{n+1}; \\ (n-1)\cdot\left(R - \dfrac{n-1}{n+1}\cdot s\right), \text{ otherwise.} \end{cases}$$

♦

We now study the suppliers' incentives to aggregate supply through a centralized aggregator. Such aggregation is a reasonable response if it improves suppliers' profits. Further, it is necessary and sufficient that the *total* supplier profits increase by buyer-aggregation. To see this, observe that if the total supplier profits fall, then at least some suppliers will refuse to participate in the auction scheme, and the mechanism breaks down. On the other hand, if the total supplier profits increase via aggregation, then even suppliers who lose money by aggregation can be induced to participate by appropriate side-payments (made in the form of subsidies for adoption). Such side-payments are incentive compatible for suppliers who do make more money by using the aggregator. In light of the above, we study the difference in supplier profits under the decentralized and aggregation regimes, to derive the conditions under which aggregation of supply coupled with the auction mechanism is feasible. The following proposition states our findings.

Proposition 5: *[Comparison of suppliers' Decentralized and Aggregation profits]: Supplier profits under the two regimes are ranked as follows:*

$$\pi_D^* = n \cdot S_D^* > \pi_A^* \forall R, s, n.$$

Thus, suppliers are always strictly worse off under aggregation of supply coupled with the auction mechanism, even though buyer valuations are uncertain. ♦

Proposition 5 establishes that *even a coordinated auction mechanism in a centralized market, with suppliers setting quantities, is dominated by the uncoordinated, decentralized posted price solution.* This result holds independent of the number of markets aggregated (*n*) or the Value Concentration Ratio. In the Decentralized Regime, given the uncertainty about the buyer's valuation, the supplier incurs an opportunity cost arising from lost sales through overpricing or sub-optimal revenues through underpricing. The aggregator in the Aggregation Regime seeks to eliminate this opportunity cost by running an auction. As we know, the auctioneer pays an information rent whose magnitude is identical under the different types on auctions (by the Revenue Equivalence Theorem). Proposition 5 shows that the information rent under aggregated auctions is always greater than the opportunity cost under Decentralized Markets of lost sales through overpricing or sub-optimal revenues through underpricing, given suppliers' uncertainty about buyer valuations.

A reasonable question that arises at this juncture is how the number of bilateral markets – i.e. number of buyers and sellers – affects the *difference* in profits between the Decentralized and Aggregate regimes. Perhaps, as more buyers and sellers are aggregated, the difference may fall to zero thus producing nearly the same outcomes pre- and post-aggregation. To investigate this, we examine the behavior of $\Delta\pi$, the difference in profits under the two regimes. We focus on the interesting (non-trivial) case that $\frac{R}{s} \leq \frac{3n-5}{n+1}$, wherein the solutions under both the Decentralized and Aggregation regimes are interior points of the feasible range of quantities. This leads us to our next proposition.

<u>Proposition 6:</u> *The difference in aggregate supplier profits between Decentralized and Aggregate regimes is <u>increasing</u> in the number of buyers – i.e. more the number of buyers, greater is the loss from Aggregation.*

We will discuss the drivers of our analytical results in the Section that follows, test these experimentally to verify if there exists empirical evidence in support of our theoretical analysis, and examine the managerial insights behind our key findings.

4.1 Discussion and Numerical Examples

An important contrasting result that emerges from the analysis in the preceding Sections is that even with quantity coordination across suppliers, enabled by the Forward Aggregator, suppliers are generally worse off from aggregation and can at best do as well as they can under the Decentralized Regime. We now investigate what parameters drive these results, and their impact on the magnitude of market outcomes (gains and losses to buyers and suppliers respectively).

Two key variables that drive market outcomes (i.e., prices, quantities and profits) in both the Decentralized and the Aggregate regimes are: the Value Concentration Ratio and the number of markets sought to be aggregated. We will show that both variables *jointly* determine the extent of domination of the Decentralized market structure over the Aggregation regime (for suppliers), the optimal price discovery mechanism (auctions or posted-prices) and the value of coordination via a centralized market operator as opposed to operating in an uncoordinated, fully decentralized system of markets.

[INSERT FIGURE 1 ABOUT HERE]

Figures 1 amplifies on the results of Proposition 5. For low values of the Value Concentration Ratio (more precisely, the range given by $\frac{R}{s} < \frac{3n-1}{n+1}$), it turns out that auction prices are actually lower, i.e., $P_A^* < P_D^*$. In the complementary range $\frac{R}{s} > \frac{3n-1}{n+1}$, the reverse holds, i.e., $P_A^* > P_D^*$. (We can show that $P_A^* = P_D^*$ *iff* $\frac{R}{s} = \frac{3n-1}{n+1}$.) Nevertheless, in the entire range of parameter values, and irrespective of the ordering of prices, the profits from the decentralized, posted-price markets strictly dominate those from the auction market. As we mentioned earlier, an auction market is usually the seller's response to uncertainty about demand (buyer valuations). However, in an auction, it is necessary to provide incentives to the buyers to reveal their valuations truthfully by bidding their WTP. This is achieved in the Vickrey auction through the artifice of having winners pay the highest losing bid – the buyers are thus able to retain some surplus for themselves which is the difference between their valuations and the highest losing bid (in return for revealing their WTP). This is frequently referred to as an "information rent" in the Mechanism Design literature. It turns out that paying such an information rent is sub-optimal, since the *opportunity cost* in the Decentralized regime (due to suppliers' ignorance of buyer valuations) through overpricing (which results in lost sales) or underpricing (which leads to sub-optimal revenues) is *less* than the *information rent* that needs to be paid to buyers in the Aggregation regime. Thus, the monopolist would be better off with posted prices even with the attendant risk of overpricing (or underpricing) rather than with paying the information rent to buyers via the auction mechanism. As a result, the auction mechanism produces a lower profit than the posted price mechanism even in the presence of demand uncertainty. Thus the suppliers would not run a centralized auction market under these conditions. Note that this result is independent of the specific (Vickrey) auction format. If the supplier were to choose a different auction format, the buyers would shade down their bids, and by the Revenue Equivalence Theorem, the supplier would make the same expected revenues as the Vickrey auction, implying that the information rent paid to the buyers is the same.

An observation that both researchers and practitioners have made is that the benefits of aggregation increase with the *scale* of aggregation, manifest in the number of suppliers that are brought to the same trading platform [Chappuis 2001, Kaplan 2000]. Proposition 6 already established that the *absolute* difference in aggregate supplier profits between Decentralized and Aggregate regimes moves in a direction opposite to that predicted by the previous observation, i.e., this is *increasing* with the scale of aggregation. We now examine the *ratio* of profits from the aggregated market to those from the decentralized markets, given by $\frac{\pi_A^*}{\pi_D^*}$. Figure 2 below shows how this profit ratio behaves as the scale of aggregation increases, for different values of the Value Concentration Ratio.

[INSERT FIGURE 2 HERE]

It is clear from Figure 2, that as the number of suppliers that are aggregated on the same platform increases, the performance of the aggregate market does improve. The ratio of profits from the two markets approaches unity, thereby indicating that as the scale of aggregation increases, the relative profitability of aggregation improves. However it never exceeds the profits from the decentralized regime. A second trend that can be seen from Figure 2 is that for higher values of the Value Concentration Ratio, the ratio of the two profit streams is closer to unity. This is a graphical manifestation of the reasons that we have discussed above which can be summed up as follows – the greater the Value

Concentration Ratio, the less is the information rent that is paid by the centralized auctioneer (the aggregated suppliers) to the buyers. As a result the profits from the auction market and the posted price markets converge.

In the next Section, we describe a series of experiments we conducted to test the validity and robustness of our theoretical findings-- vis-à-vis empirical evidence about the behavior of buyers and suppliers in electronic B2B markets.

5. Experimental Analysis

We have been conducting several experiments since 2002 to investigate how buyers and suppliers behave in these markets. Our experiments spanned several countries (Singapore, Thailand, India, US). We used the Wharton B2B electronic market platform – VASE (the Virtual Auction Server Engine) – that supports multiple auction types and market structures to run the experiments. Experimental subjects included traders of financial securities, direct and indirect procurement specialists of large industrial firms that buy and sell their products via auction markets, senior executives of manufacturing firms and finally, graduate and undergraduate students from the US and India. The objective of the experiments was to test if the predictions of the model would be validated. More specifically we tested the following: (1) if the actual bidding behavior of buyers in electronic B2B markets would result in revenues to suppliers greater than or less than those predicted by theory (2) the impact of the scale of aggregation (given by n in our model) on supplier revenues and (3) the impact of buyer heterogeneity (given by R and s in our model) on supplier revenues. Each experiment was varied according to the auction parameters, i.e., the number of buyers (N), and the distribution of values given by the lower and upper bounds of the support (R and s). The distributions of buyer valuations were calibrated to exactly match the distribution characteristics that we used in the theoretical analyses in the preceding sections. Each buyer was assigned his value of the good based on a random draw (from the distribution); the total number of bidders, and the distribution and support of the other buyers' valuations were all common knowledge in each experiment. Buyers knew that the auctions were based on private valuations—i.e., each buyer's value for the good auctioned was unaffected by the values of other buyers for that good. More details of the experimental design, including the types of experimental subjects, the instructions and incentives provided to them, and the experimental methodology, are provided in Technical Appendix B.

In order to eliminate trivial cases, we focus in this discussion on those auctions where the parameters were set so that the optimal solution was an interior point of the distributional support ([L,U] = [R-s, R+s]).

The results below are derived from 38 different experiments.

1. The actual revenues (experimental) that accrue to suppliers are generally lower than the theoretical Decentralized (pre-aggregation) revenues.
2. The actual revenues (experimental) that accrue to suppliers are generally lower than the theoretical Aggregation revenues.

The summary of experimental data collected can be seen in Table 2 in Technical Appendix B. Figures 3 and 4 make this clear graphically.

[INSERT FIGURES 3 AND 4 HERE]

We term the phenomenon wherein the actual experimental revenues post-aggregation are less than the Decentralized (pre-aggregation) revenues as the *Revenue Deficit from* *aggregation*. We now investigate the extent and behavior of the Revenue Deficit and compare the experimental results with the predictions of the theoretical model.

The Revenue Deficit:

It is clear from the table that *in all but five of the thirty-eight experiments*, supplier revenues observed under aggregation (experimental B2B market) are less than the revenues in the Decentralized Markets Regime characterized by bilateral contracts-- and in most cases, significantly so. What the data show is that when suppliers are aggregated in a B2B market, <u>the resulting revenues to the supplier from the auction are not only less than the Decentralized (pre-aggregation) revenues, but also less than the theoretical predicted revenue from that aggregated market</u>. The experimental evidence not only fully supports the findings of the model, it shows that, the model's predictions are a conservative estimate of the actual effect size. We analyzed the extent of the Revenue Deficit as a percentage of the revenues from the Decentralized Regime for the 38 experiments listed in Table 1. The findings are summarized in the Histogram of Figure 5.

[INSERT FIGURE 5 ABOUT HERE]

It is evident from Figure 5 that in a disproportionate majority of cases, suppliers' revenues were greater under Decentralized markets. In fact the two most frequent outcomes were Revenue Deficits of the order of 4%-8% or greater than 8%. Only in a few cases (5 out of 38) did the post-aggregation revenue in experimental markets exceed the pre-aggregation revenues. The above observation led us to model the Revenue Deficit as a function of the auction parameters – the number of bilateral markets (*n*) and the characteristics of the support (*R* and *s*). In other words,

$$\text{Revenue Deficit, } RD = \pi_D - \pi_A{}^{Exptl} = f\left(n, R, s\right)$$

To test this proposition we regressed the Revenue Deficit as a function of

N, R and s given by the regression equation given below:

$$RD_i = \beta_1 + \beta_2 n_i + \beta_3 R_i + \beta_3 s_i + \varepsilon_i$$

where the data from the i^{th} auction is subscripted by i. The results are presented in Table 1 below.

[INSERT TABLE 1 ABOUT HERE]

The results of the regression in Table 1 show that as the scale of aggregation (*n*) increases, the Revenue Deficit increases. On average (across all auctions) the addition of each bilateral market to the aggregate B2B market will *increase the Revenue Deficit* by 182 points. This shows that aggregation produces the greater loss to suppliers in larger markets - *as n increases, so does the Revenue Deficit*. This was exactly the theoretical prediction from the model (recall Proposition 6 of Section 4) and this effect is borne out experimentally.

A weaker (yet, statistically significant) effect is that an increase in mean buyer valuation (given by *R*) results in an increase in the Revenue Deficit. This would imply that where products carry a higher value to the buyer, suppliers stand to lose more from aggregation. This is consistent with the notion that the market mechanism matters. When the Decentralized Regime outperforms the Aggregation Regime, the difference in profits $(\pi_D - \pi_A)$ is increasing in the total value of the market(s) being aggregated.

To summarize, the principal findings of the model – (1) that even with quantities coordinated among suppliers (enabled by an aggregator aligned with the suppliers), the suppliers are generally worse off under aggregation and (2) the greater the scale of aggregation greater is the suppliers' resulting loss of revenue -- are strongly supported by the experimental evidence.

7 Concluding Remarks

We formulated a model of forward aggregation in business-to-business markets, i.e., the aggregation of supply by a supplier consortium. A central result that emerges from our analysis is that even by *(i)* bringing together heterogeneous buyers in a single market, *(ii)* discriminating in favor of the higher-value buyers, and *(iii)* colluding on the quantity supplied, suppliers do not stand to gain in the aggregate. Our analysis also highlights the relative efficiencies of the two most frequently used price-discovery mechanisms in these markets – posted prices and auctions. The widely held view of business-to-business exchange operators is that auctions are the suppliers' natural response to demand uncertainty. However, we find that the information rents that suppliers must pay to bidders to discover the underlying demand (via an auction) nullifies the benefits of revealing the demand. Thus we show that the conventional wisdom amongst market operators underestimates the magnitude of the information rent and overstates the value of demand revelation through exchanges and auctions. These results are strongly borne out by the empirical evidence – the analysis of experimental data makes it clear that the posted-price bilateral contracts outperform the collusive auction when it comes to aggregate supplier revenues.

We find that two factors drive the relative profitability of auction-based forward aggregation. These are the Value Concentration Ratio and the scale of aggregation. The relative profitability deficit of the forward aggregation model declines in both factors. The Value Concentration Ratio is a function of both the mean and the dispersion of buyer valuations. An increase in this ratio has a two-fold impact: as the mean increases, relative to the dispersion, the value of the lower half of the market (buyers towards the lower end of the support) increases both on an absolute and on a relative scale, thereby making that market more attractive to serve. This in turn implies that the auctioneer will release greater quantities to the market, driving his price towards the lower end of the support. We see a similar trend in the posted price markets. Prices and profits from both regimes converge asymptotically as the number of buyers (markets) increases. To summarize, *there are no gains to suppliers from aggregation even under heterogeneous and uncertain buyer valuations.*

There are several extensions to this research that need to be explored. The model can be extended by incorporating heterogeneity in suppliers' costs of production, in addition to that in buyer valuations. Consortia as modeled in our research are essentially cooperatives, presenting their own unique set of coordination (incentives) problems. While we did not focus on incentive misalignment between the consortia and the parent firms, future research should study these issues, which could further erode the advantages of aggregation. A more formal treatment of the asymmetric power of buyers and suppliers, perhaps by endogenizing the sources of bargaining power in these markets, would also be interesting. There could be other efficiency gains to suppliers from aggregation, such as transaction cost reduction through automation– but such benefits pertain not so much to the invisible hand of price as to the visible hand of coordination costs. Finally, the same problem can be extended into a multi-period context where buyers could use inventories strategically between periods, while suppliers could coordinate through an inter-period quantity specification game.

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Figures and Graphs

Figure 1: Comparison of Supplier Profits and Prices under Aggregate and Decentralized Regimes for varying Value Concentration Ratios (given by $\frac{R}{s}$).

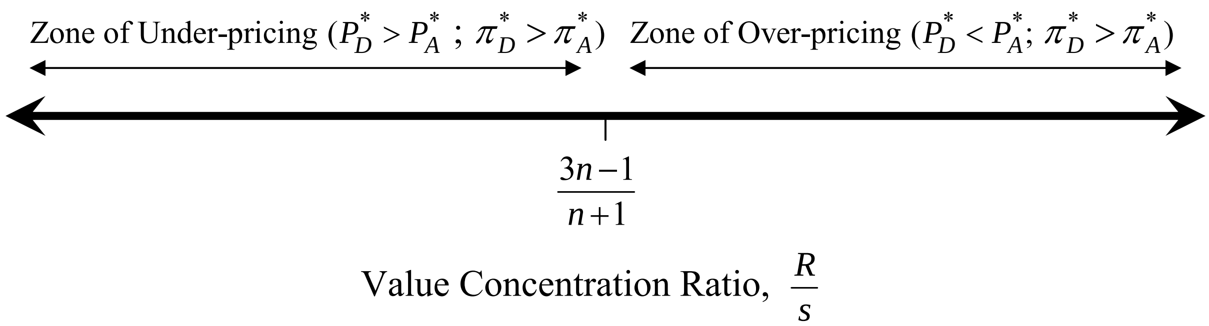

Figure 2: Profit Ratio (PR) for Suppliers: Ratio of Profits Under Aggregate Vs. Decentralized Markets For Varying Value Concentration Ratios (given by $\frac{R}{s}$).

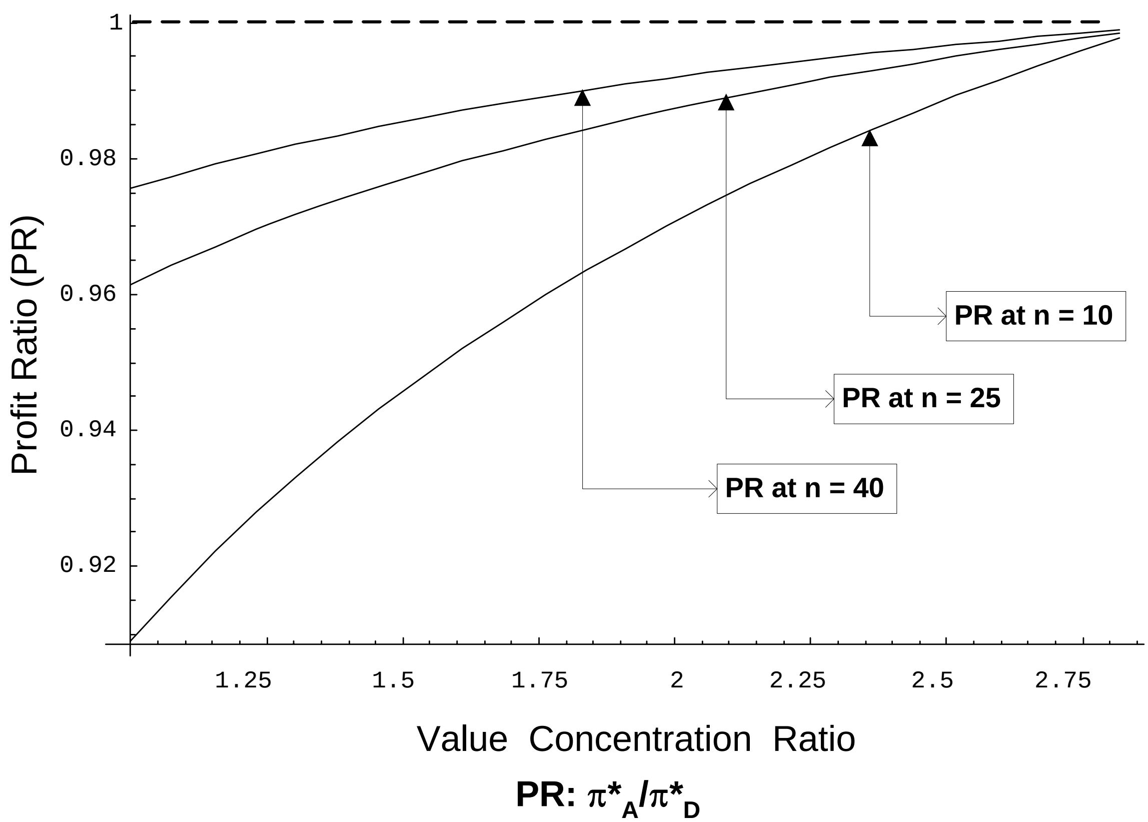

Figure 3: Revenue Deficit as a function of the number of markets aggregated. We find that this difference is largely positive over the entire range.

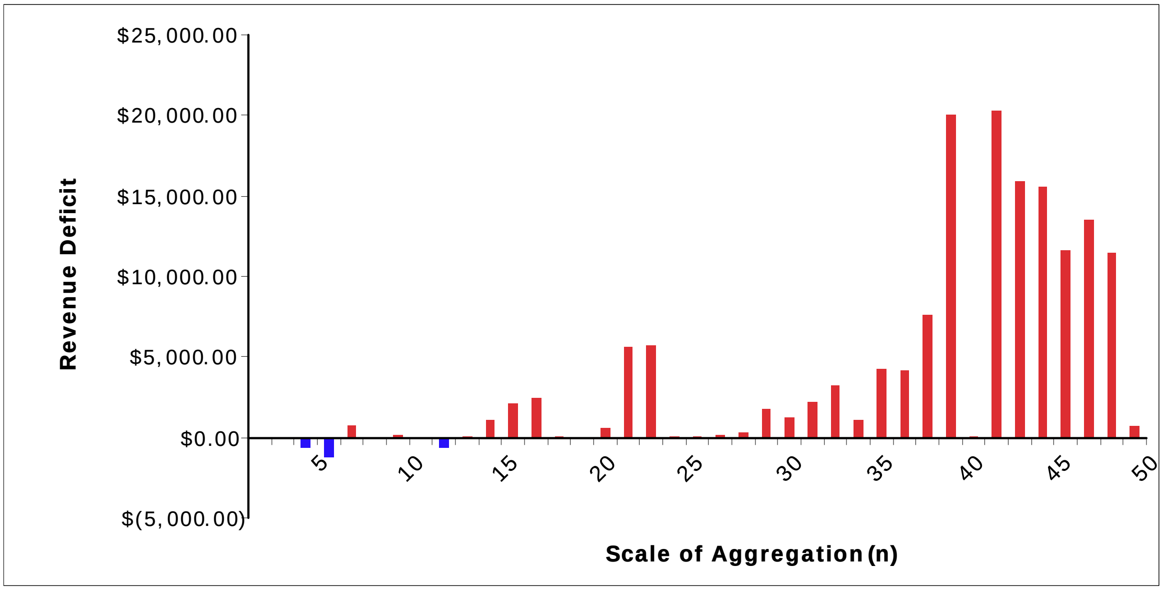

Figure 4: Revenue Difference under Aggregation: This is the difference between predicted and empirically observed supplier revenues in the Aggregate Regime, as a function of the number of markets aggregated. We find that this difference is largely positive over the entire range.

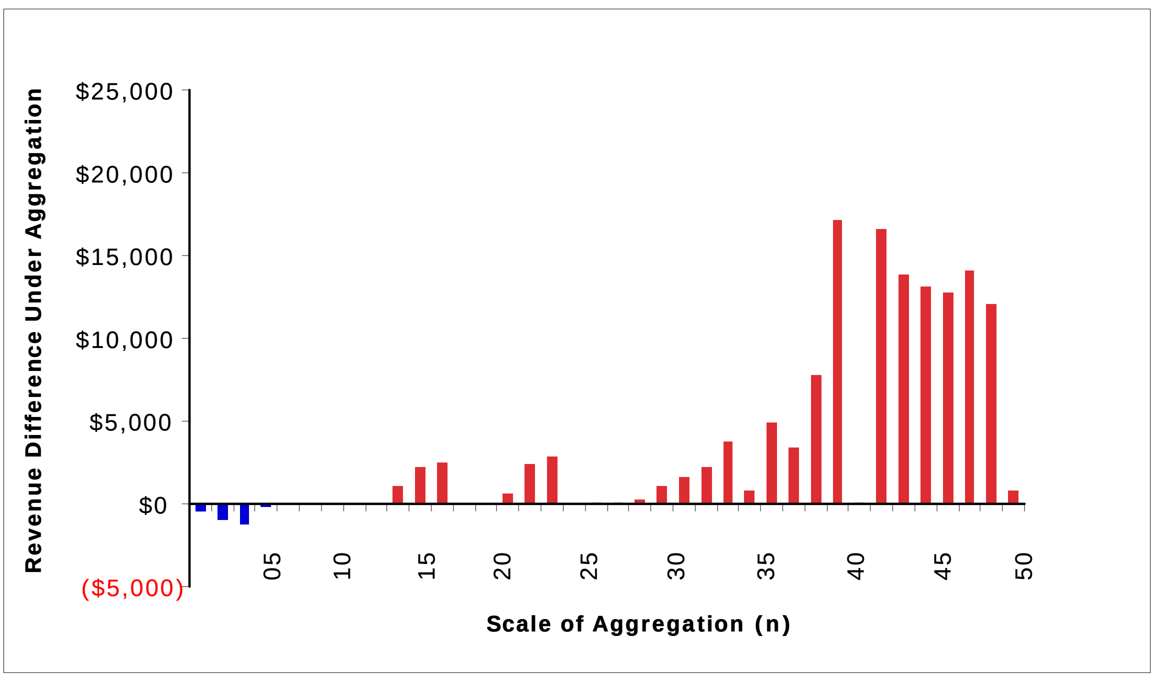

Figure 5: Revenue Deficit measured as a percentage of the revenues from the Decentralized Regime.

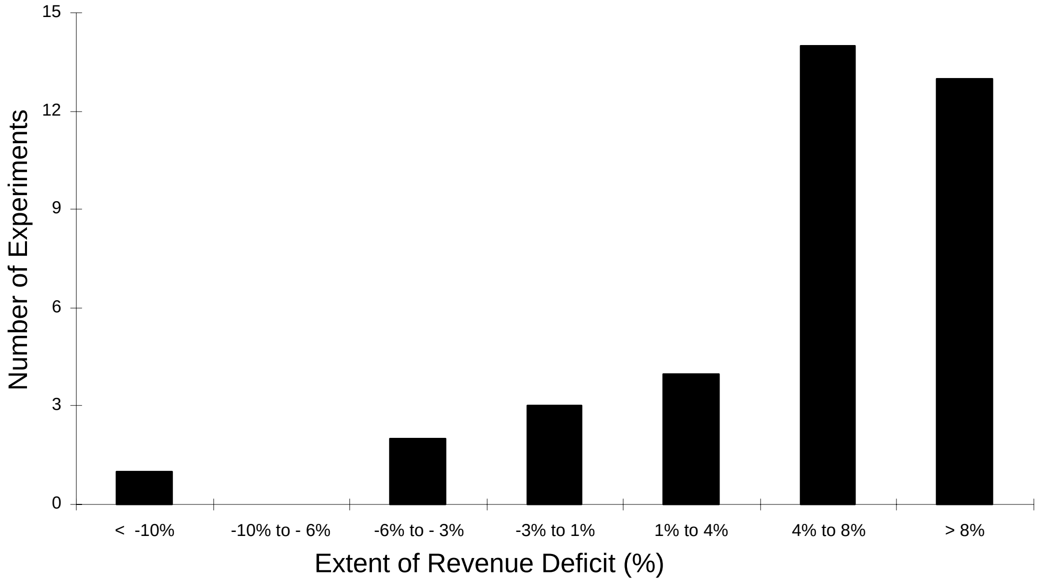

Table 1: Revenue Deficit: Results of OLS Regression

Regression Statistics	
Multiple R	0.914
R Square	0.835
Adjusted R Square	0.820
Standard Error	2558.716
Observations	38

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	-4314.85	999.94	-4.32	0.0001
Scale of Aggregation (N)	181.90	37.50	4.85	0.0000
R (Mean of Support)	1.91	0.27	7.00	0.0000
s (dispersion of the valuation)	-1.30	0.38	-3.44	0.0016