A BEHAVIORAL ECONOMIC ANALYSIS OF THE DEMAND FOR MONEY IN HUMANS: THE EFFECTS OF UNIT PRICE STRUCTURE, PRICE DESCRIPTIONS, AND PRICE SEQUENCE

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This study investigated the effects of unit price structure, unit price descriptions, and unit price sequence on the demand for money in humans. Six groups of 3 participants solved multiplication problems in exchange for money under various unit prices. Consumption of money decreased as the unit price increased across all conditions. However, the data also showed that: (a) fixed price structures produced slightly more elastic demand than did variable price structures, (b) price descriptions produced more elastic demand under variable price structures but had little or no effect under fixed price structures, and (c) the alternate sequence used with fixed price structures produced slightly more elastic demand.

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CHAPTER 1

INTRODUCTION

Since its introduction to the experimental analysis of behavior, the field of behavioral economics has generated numerous avenues of research. Behavioral economics has also proven to be a very useful framework for analyzing and interpreting results from other lines of research (Bickel, DeGrandpre, & Higgins, 1995). More specifically, behavioral economics has added a new approach to other methods of investigating choice behavior. The basic premise of the behavioral economic approach is that a behavioral experiment functions as an economic system, and the characteristics of that system can determine the results (Hursh, 1980). By applying concepts from microeconomics to behavior, behavioral economics focuses on how available behavioral resources are distributed among available reinforcers, and the factors that control the distribution of those resources (Hursh, 1993).

With these new methods of analysis, behavioral economics has contributed new dependent and independent variables as well as a variety of other useful concepts that have not only led to new considerations of how reinforcers function, but have also led to the development of new technologies for work in applied areas (Bickel, Green, & Vuchinich, 1995). In the majority of research conducted in behavior analysis, the primary dependent variable has been rate of responding. Behavioral economics, however, has shifted the focus away from rate of responding and has instead turned to total daily consumption as the primary

dependent measure of behavior in economic studies (Bickel et al., 1995; Bickel, Hughes, DeGrandpre, Higgins, & Rizzuto, 1992; Hursh, 1993). Consumption does not refer to the actual ingestion of a reinforcer; rather, it has been defined by Bickel, DeGrandpre, Higgins, and Hughes (1990) using the following formula:

Consumption = Number of response requirement completions X reinforcer magnitude

In a behavioral economic framework, rate of response is considered to be a secondary dependent variable in that it may control consumption indirectly (Hursh, 1993).

Behavioral economics has shown that the interaction between response requirement (i.e., number of responses) and reinforcer magnitude directly influences consumption (Hursh, 1980). The quantification of this interaction has yielded the major independent variable in behavioral economics, which is termed unit price. Price, in this case, however, is not only the number of responses required to obtain a reinforcer; it is the number of responses required, or the amount of work expended, per unit of the reinforcer (Bickel et al., 1992; Hursh, Raslear, Shurtleff, Bauman, & Simmons, 1988). According to Hursh (1991), "Price is best understood as a cost-benefit ratio that describes the amount and effort of work required for each unit of reinforcement" (p.379). Furthermore, Hursh (1991) developed the following formula for unit price in terms of that cost benefit ratio:

$$\text{Unit Price} = \frac{\text{Responses per reinforcer x Effort}}{\text{Size of reinforcer}}$$

For example, using this formula a unit price of 5 could be obtained by requiring five responses to obtain 1 unit of the reinforcer while holding the effort requirement constant. A unit price of 10 could be obtained by requiring 50 responses to obtain 5 units of the reinforcer, also while holding the effort requirement constant. According to unit price analyses, different response requirement and reinforcer magnitude combinations that yield the same unit price should have the same effect upon consumption (DeGrandpre, Bickel, Hughes, Layng, & Badger, 1993). For example, a unit price of 10 composed of a response requirement of 50 over 5 units of the reinforcer should be functionally equivalent to a unit price of 10 composed of a response requirement of 100 over 10 units of the reinforcer. A recent study by Madden, Bickel, and Jacobs (2000), however, failed to support this prediction in that different compositions of unit price produced different levels of consumption. Further research in this area is needed to evaluate this aspect of unit price.

Depending on the type of reinforcer being used, the unit of the reinforcer will vary. For example, studies involving the use of drugs typically use the number of mg of a particular drug as a unit (Hursh, 1993), whereas in studies investigating cigarette smoking the unit is calculated in terms of the number of puffs on a cigarette (Bickel, DeGrandpre, Hughes, & Higgins, 1991; see also Bickel et al., 1995; DeGrandpre, Bickel, Higgins, & Hughes, 1994). Reinforcer units are typically expressed in terms of weight or volume when food and water are being used as reinforcers (Green & Rachlin, 1991), and when money has been used as a reinforcer, the unit has been expressed in terms of cents (DeGrandpre et al., 1994).

One of the major advantages of the concept of unit price is that it allows multiple independent variables to be combined into a single variable (Bickel et al., 1995; DeGrandpre et al., 1993). Furthermore, because unit price is composed of multiple variables, it allows the opportunity to select which part of the ratio to manipulate. For example, not only the schedule, but the effort required for each response as well as the magnitude of the reinforcer could be manipulated to study different aspects of unit price.

The relationship between unit price and consumption is typically described in economic terms as demand (Hursh, 1980). A fundamental principle of behavioral economics, known as the law of demand, states that as the price for a commodity increases the demand for that commodity will decrease (Bickel et al., 1992). Studies investigating this phenomenon using unit price have produced consistent results using a variety of different reinforcers; consumption of a particular commodity decreases in relation to increases in unit price (see DeGrandpre et al., 1993). The mathematical function of the relationship between consumption and unit price is the demand curve, which is expressed using logarithmic coordinates in order to show the proportional change in consumption that occurs as the price for that commodity increases (Hursh et al., 1988). In logarithmic coordinates, proportional changes in consumption between the different unit prices are equal to the slope of the line denoting the demand curve, which is typically a positively decelerating function of increasing unit prices (DeGrandpre et al., 1993, 1994). Also plotted in logarithmic coordinates is the total amount of responding that occurs at each unit price, referred to as the response or work output (Hursh, 1993).

Typically, increasing unit price produces a bitonic, or inverted U-shaped function for response output (DeGrandpre et al., 1993; Hursh, 1993).

The extent or the degree to which consumption changes as unit price increases is referred to as elasticity (DeGrandpre et al., 1993). If consumption for a commodity changes very little as the unit prices increases, or if the proportional change in consumption is less than the proportional change in price, the demand for that commodity is said to be inelastic or the commodity itself is said to be inelastic (DeGrandpre et al., 1993; Hursh, 1984, 1991). In order for this to occur, the total amount of responding must increase as the unit price increases, which is also termed defense of consumption (Hursh, 1993). For example, a certain number of responses need to occur in order to achieve a particular level of consumption at a low unit price. If that same level of consumption is to be maintained (i.e., defended) at a higher unit price, then more responses will be required due to the increase in price per unit of the commodity. Additionally, in situations where there is a limited time for responding, response rate must increase as well in order to achieve the same level of consumption (Hursh, 1980). For example, if during a 30-min session at a low unit price, 400g of food are consumed, responding will have to occur at a higher rate at a higher unit price to achieve the same consumption level due to the fact that it takes more responses to earn each unit of the commodity at higher prices.

If consumption for a commodity decreases dramatically with increases in price, or if the changes in consumption are proportionately greater than changes in price, the demand for or the actual commodity is said to be elastic (DeGrandpre et al., 1993; Hursh, 1984, 1991).

At the point at which demand becomes elastic, the total amount of responding for the commodity decreases as the unit price increases and consumption is not defended. According to Hursh (1993), the distinction between elastic and inelastic commodities is best defined as a continuum in that demand for any commodity will become elastic if the unit price is increased sufficiently. The point at which demand changes from inelastic to elastic is labeled P-max by Hursh (1993), and also corresponds to the point of maximum responding illustrated by the bitonic function of response output. Therefore, cases in which the elasticity increases as unit price increases are said to exhibit mixed elasticity (Hursh, 1980; DeGrandpre et al., 1993)

An important point is that elasticity is not an inherent property of the commodity (Hursh, 1980, 1984, 1993). Certain commodities may tend to generate more elastic demand than others, such as luxuries, whereas other commodities necessary for survival tend to generate inelastic demand. However, elasticity is directly related to the physiological conditions of the organism as well as the presence of certain environmental variables (DeGrandpre et al., 1993; Hursh, 1984). According to Hursh (1984), there are at least four variables that can alter the elasticity of demand: (a) the nature of the commodity (e.g., luxury or necessity), (b) the species of the consumer, (c) the availability of substitutes, and (d) the economic context.

In terms of the nature of the commodity, studies have shown that commodities such as food and water produce much more inelastic demand than other commodities such as electrical brain stimulation, drugs, and even room illumination (see Hursh, 1980, 1984). Responding generally continues for longer periods of time at increasing unit prices when the commodities are

essential for survival, however, the environmental conditions present during responding may influence the consumption of both necessities and luxuries.

The species of the consumer may affect elasticity in terms of different physiological needs. Hursh (1984) discussed an experiment that tested the elasticity of water with two different species of packrats that had either inhabited arid or moist environments. Results showed that water was significantly more elastic at higher prices for the packrats that lived in arid environments, and inelastic for those packrats living in moist environments (see Hursh, 1984). The more general law of demand (i.e., decreases in consumption as a function of increasing prices), however, has been demonstrated across a number of different species and is not considered to be species dependent (DeGrandpre et al., 1994).

One of the largest areas of research in behavioral economics has been concerned with the third factor that Hursh (1984) discussed: the issues of substitutability, complementarity and independence. All three of these terms represent a continuum of possible interactions that may occur between different commodities, with substitutability and complementarity on the ends of the continuum and independence falling in the middle (Bickel et al., 1992; DeGrandpre et al., 1994; Green & Freed, 1993; Hursh, 1980, 1984, 1993). Specifically, the relationship is between the consumption of one commodity and the price of the other commodity (Hursh, 1993). According to Green and Freed (1993), two commodities may be substitutable if they serve similar purposes; however, this is not a defining feature of a substitutable relationship. In this type of relationship, if the price of one commodity increases, consumption for that commodity decreases and consumption of the other commodity (i.e., the substitute) increases

(Bickel, et al., 1992; DeGrandpre et al., 1994; Green & Freed, 1993; Hursh, 1980, 1984, 1993). In cases where a substitute is present, elasticity for the other commodity is likely to be high (Green & Freed, 1993). Two commodities are said to be complements if they are used together (Green & Freed, 1993). When commodities are complements, an increase or decrease in the consumption of one of the commodities produces the same effect in the other commodity (Bickel, et al., 1992; DeGrandpre et al., 1994; Green & Freed, 1993; Hursh, 1980, 1984, 1993). Therefore, in this case, the effect on elasticity depends on whether consumption decreases or increases. For example, if the consumption of one of the commodities decreases, consumption of its complement will also decrease and perhaps become elastic. If altering the price of one of the commodities has no consistent effect on the consumption of the other commodity, those commodities are said to be independent (Bickel, et al., 1992; DeGrandpre et al., 1994; Green & Freed, 1993; Hursh, 1980, 1984, 1993).

The fourth variable discussed by Hursh (1984) concerns the economic context in which the organism is operating. The two economic contexts discussed in behavioral economics are labeled open and closed economies. In an open economy, total consumption of the commodity is not solely the result of the amount of responding occurring within a session (Hursh, 1980, 1984, 1993; Timberlake & Peden, 1987). A common way to distinguish an open economy is if the particular commodity is available outside of the experimental situation (Timberlake & Peden, 1987). As a result of having an alternative source of the commodity, demand is typically very elastic in open economies (Hursh, 1980, 1984, 1993; Timberlake & Peden, 1987). By contrast, in a closed economy, total consumption is solely determined by the amount

of responding during a session (Hursh, 1980, 1984, 1993; Timberlake & Peden, 1987). In this situation, no alternative sources of the commodity are available (Timberlake & Peden, 1987). In closed economies, therefore, demand is typically more inelastic (Hursh, 1980, 1984, 1993; Timberlake & Peden, 1987).

In order to determine whether or not a commodity is elastic or inelastic, the proportional change in consumption that occurs between unit prices, or the slope of the demand curve, is quantified in terms of own-price elasticity (Hursh & Bauman, 1987; Samuelson & Nordhaus, 1985). This measure is derived by using the following formula taken from Samuelson & Nordhaus (1985):

$$E_D = \frac{\hat{I}Q}{(Q1 + Q2)/2} \div \frac{-\hat{I}P}{(P1 + P2)/2}$$

where $\hat{I}Q$ is the is the change in quantity consumed of a commodity, Q1 and Q2 are the quantity consumed under price 1 and price 2, respectively, $\hat{I}P$ is the change in price, and P1 and P2 are the two prices, respectively. If the resulting elasticity coefficient is less than 1.0, the commodity is said to be inelastic between those two prices (Bickel et al., 1992). If the coefficient is equal to greater than 1.0, the commodity is said to be elastic between those prices (Bickel et al., 1992). Because certain commodities can produce mixed elasticity, coefficients are typically calculated for each change in unit price (Bickel et al., 1992).

In a later study, DeGrandpre et al. (1994) used a different formula for elasticity reported by Allison (1983). With this formula, the obtained elasticity coefficients are either positive or negative depending upon the slope of the demand curve. With the Samuelson and

Nordhaus (1985) formulation, the elasticity coefficients are positive when the slope of the demand curve is negative and negative when the slope of the line is positive. Aside from this difference, however, the information provided by each formulation is basically identical and both are accepted as viable alternatives for analyzing demand curves.

The majority of research conducted in behavioral economics focuses on how consumption interacts with unit price and how the presence or absence of other variables affect that interaction. Typically, most of the earlier work in behavioral economics has been conducted with nonhumans investigating commodities such as food and water, and in some cases, electrical brain stimulation. For example, an early study by Hursh (1978) examined the factors controlling responding for food and water by rhesus monkeys under different economic contexts (i.e., open or closed economy). Timberlake and Peden (1987) also investigated open and closed economies as well as the type of responding produced by each using pigeons. Another study by Hursh et al. (1988) investigated the validity of unit price by using rats responding for food. Tests of substitutability were also conducted with similar types of commodities, as in Green and Rachlin (1991) where they tested the substitutability of electrical brain stimulation, food, and water in rats. In another test of unit price, Foltin (1994) looked at different reinforcer magnitude and response requirement combinations and their effect on consumption using baboons responding for food.

Other areas of research in behavioral economics involve the use of drugs as commodities. The application of behavioral economics to the study of drug self-administration has led to new ways of conceptualizing drug abuse as well as offered new methods of treatment

(Hursh, 1993). As with commodities such as food and water, much of this research has been conducted with nonhumans. Although some of the studies conducted in this area only involve the use of one drug, most of the studies examine substitutability either using two drugs, or one drug and nondrug reinforcer (Bickel et al., 1995). For example, Elsmore, Fletcher, Conrad, and Sodetz (1980) investigated responding for heroin under increasing unit prices using baboons. Another study by Carroll (1987a) investigated responding for PCP in rhesus monkeys as a function of varied concentrations of PCP. In the area of substitutability, Griffiths, Wurster, and Brady (1981) examined the substitutability of heroin and food in baboons, Dworkin et al. (1984) investigated the substitutability or morphine, food, and water using rats, Carroll (1987b) investigated the substitutability of Ethanol and PCP in rhesus monkeys, and in a later study, Carroll, Carmona, and May (1991) examined the substitutability of saccharin and PCP, also in rhesus monkeys.

Research in this area has also been conducted with humans, although not to the same extent. In a review of drug self-administration research, Bickel et al. (1995) showed that from 1966 to 1992 only 5 out of 16 studies were conducted with human participants. All of these studies with the exception of one involved testing the substitutability of two drug reinforcers. Bickel et al. (1986) did not investigate substitutability, but tested the effects of dose size on the consumption of methadone. The other four studies involved the substitutability of nicotine, in the form of cigarettes, and either coffee (Bickel et al., 1992), alcohol combined with marijuana (Mello, Mendelson, Sellars, & Kuehnle, 1980a). heroin (Mello, Mendelson, Sellars, & Kuehnle 1980b), or alcohol alone (Mello, Mendelson, & Palmieri, 1987).

Since the publication of the review in this area, more self-administration studies with humans have been conducted. DeGrandpre et al. (1994) investigated the interaction between concurrently available money and cigarette puffs, and found that consumption of both money and puffs decreased as the response requirement increased, but that money was more elastic. These two commodities were also found to be relatively independent, in that the price increases and consumption levels of one of the commodities had little or no effect on the other. More recently, Madden et al. (2000) used cigarette smoking to further test the concept of unit price and confirmed that consumption was a positively decelerating function of increasing unit prices, and work output was a bitonic function of increases in unit price. Their results failed to confirm, however, that different compositions of the same unit price (i.e., response requirement and reinforcer magnitude) would yield similar consumption levels.

An interesting application of behavioral economics, not related to self-administration research, involves the analysis of preference assessments. Tustin (1994), investigated preference for reinforcers in participants with intellectual disabilities under conditions in which prices for the reinforcers varied, and when possible substitutes were available. Results showed that preference for reinforcers was strongly affected by the price of the reinforcers as well as the availability of substitutes. These results suggest that economic variables should be taken into consideration whenever preference assessments are conducted.

As discussed previously, the majority of research conducted in behavioral economics has involved nonhumans. When humans have been used, with the exception of Tustin (1994), the majority of the commodities used in each of the studies have been some sort of drug. A

study by DeGrandpre et al. (1994), however, investigated the substitutability of a drug (nicotine) and nondrug (money) reinforcer. According to DeGrandpre et al. (1994), no previous research with money had been conducted up to that point. In that study, the unit prices for money and cigarette puffs consisted of fixed ratio (FR) response requirements of either 100, 1,000, or 2,500 and reinforcer magnitudes of either $0.05, $0.07, $0.10, or $0.20 for money, and one or two puffs for cigarettes (DeGrandpre et al. 1994). Results showed that money generated more elastic demand than cigarettes, and a minimal amount of interaction occurred between the two reinforcers.

Since the publication of DeGrandpre et al. (1994), the only study to provide a behavioral economic investigation of money has been Viken (1999). Viken (1999) examined the elasticity of money as a function of increasing the unit price for money, as well as by using different compositions of unit price. Both DeGrandpre et al. (1994) and Viken (1999) found decreases in the consumption of money as a function of increasing price, consistent with the law of demand, using different experimental procedures and experimental responses. DeGrandpre et al. (1994) had participants respond using Lindsley plungers, as is typical of most economic preparations using humans, whereas Viken (1999) had participants solve multiplication problems using a computer and keyboard. The use of different experimental procedures as well as different apparatuses serves to increase the generality of the law of demand. Additionally, considering the widespread use of money as a reinforcer in human operant research, more research on the economic properties of money is warranted. The information gained from an economic analysis of money could not only benefit future research in behavioral

economics, but research in any area of the experimental analysis of behavior that uses monetary compensation.

In general, conducting research with humans involves different procedural considerations than conducting research with nonhumans. One of the biggest differences is that the use of human participants involves the consideration of verbal behavior and how it may affect performance in an experimental setting. More specifically, because humans can emit and respond to verbal behavior, a major procedural question involves whether to use instructions when conducting research with humans. According to Vaughan (1989), the role of instructions became a major independent variable in human operant research in the mid-1970s. This issue still continues to be investigated in present research as well.

The majority of research in this area has been concerned with the differences generated when responding is instructed versus when it is shaped by experimental contingencies (Vaughan, 1989). Many studies have found that when responding (both nonverbal and verbal) is instructed, it is less sensitive to changes in experimental contingencies than when it is shaped (Catania, Matthew, & Shimoff, 1982; Matthew, Shimoff, Catania, & Sagvolden, 1977; Shimoff, Catania, & Matthews, 1981).

An important distinction in this line of research, however, involves the type of instruction or description that is given. Some descriptions, labeled performance descriptions, give information on how to respond efficiently (e.g., press fast, or press slow) whereas contingency descriptions state what is required to earn the reinforcer (e.g., you can earn points after a random number of presses). Matthews, Catania, and Shimoff (1985) investigated the

differences between these two types of descriptions and how they affected responding on random ratio (RR) and random interval (RI) schedules of reinforcement. Results showed that when participants' verbal behavior was shaped to provide contingency descriptions of RR and RI schedules, their responding on the two schedules was undifferentiated and thus "insensitive" according to their sensitivity criteria. When their verbal behavior was shaped to provide performance descriptions, responding differentiated across the schedules.

In a series of follow-up studies, Catania, Shimoff and Matthews (1989) further investigated this finding. As in Matthews et al. (1985) these studies involved shaping participants' performance or contingency descriptions and testing their performance on RR and RI schedules. Several variations on the shaping procedures and many different antecedent manipulations were investigated as well (for a more detailed discussion see Catania et al., 1989). Similar to the findings of Matthews et al. (1985), Catania et al. (1989) showed that shaped performance descriptions produced differentiated RR and RI schedule performance, whereas shaped contingency descriptions did not. These authors did report, however, that when contingency descriptions were accompanied by accurate performance descriptions, differentiated responding occurred (Catania et al., 1989).

When considering these findings in a behavioral economic framework, some aspects are more relevant than others. For example, the issue of sensitivity to contingencies in economic experiments does not closely parallel the sensitivity issues in reinforcement schedule research. The only measure of "sensitivity" in economic experiments is the degree of elasticity, but no "typical" degree of elasticity exists for any commodity at a given price, so there is no

benchmark by which to judge performance sensitivity in the manner of Catania et al. (1989). Nevertheless, the issue of whether instructions affect the economic characteristics of behavior is relevant. In a behavioral economic experiment, a description of the unit price in effect for that particular session is a kind of instruction that could be labeled a contingency description. However, because the experimental context and the procedures are so different in economic experiments (including, for example, the participant's ability to terminate the session at anytime) it is not clear whether a contingency description in an economic experiment is the same as a contingency description in traditional reinforcement schedule research.

In several past studies, information about the unit prices has been provided to the participants. For example, Bickel et al. (1991) included the response requirement and reinforcer magnitude for cigarette puffs in effect for each session as part of the daily instructions. Similarly, DeGrandpre et al. (1994) listed response requirements on paper for both money and cigarette puffs at the beginning of each session. More recently, Madden et al. (2000) also gave participants an instruction sheet specifying response requirements and reinforcer magnitudes for cigarette puffs in each session. Bickel et al. (1992), however, did not report whether or not they provided participants with unit price information. Therefore, it seems that most studies provide the information, but some may not. The effects of providing unit price descriptions on consumption have not been directly investigated.

Based on the amount of traditional schedule research demonstrating that instructions can influence responding, it is important for this issue to be investigated in a behavioral economic framework. Any effects could have significant implications for future research in

behavioral economics with humans and could also raise questions concerning the results found in previous research.

One area that has been the subject of years of operant research, but has not been specifically addressed in the behavioral economic literature, is the effect of particular schedules of reinforcement. Schedules are used to program the response requirement portion of the unit price ratio, and by far the most commonly used schedule has been the FR schedule (Bickel et al., 1991; Bickel et al., 1992; Bickel & Madden, 1999; Foltin, 1994; Hursh et al., 1988; Madden et al., 2000). Any unit price in which the response requirement remains constant could be said to involve an FR schedule. At least one study is known to have been conducted using variable interval (VI) schedules with nonhumans (Hursh, 1978), and another study conducted by Green and Rachlin (1991) involved the use of variable ratio (VR) schedules with nonhumans. Considering the well-documented findings that different schedules influence responding in different ways (Ferster & Skinner, 1957), it is possible that the schedule used to construct the response requirement component in a unit price formulation could have particular effects on consumption. Furthermore, it is likely that this effect would be most apparent between FR and VR schedules in that VR schedules have been consistently found to produce higher response rates and greater resistance to extinction (Catania, 1998). Up to this point, however, no systematic study comparing unit prices constructed with FR and VR schedules has been conducted with either nonhumans or humans.

The order in which the unit prices are presented may also be a variable affecting consumption in a manner usually described as a sequence effect (Perone, 1991). Behavioral

economic studies have varied considerably in the sequences of unit price exposure. For example, Bickel et al. (1992) presented the unit prices in a random sequence, whereas DeGrandpre et al. (1994) used what they termed a quasi-random sequence. Madden et al. (2000) exposed participants to the unit prices in a mixed order of ascending and descending prices depending upon the comparisons being investigated. In some cases, the presentation order is dependent upon the participant's level of responding (see Green & Rachlin, 1991). In another study, Bickel et al. (1991) exposed participants to every permutation of the three prices used. Although several different methods have been used, no specific investigation of possible sequence effects has been conducted.

The purpose of the present experiment was to investigate several of these unexplored issues within a behavioral economic framework. More specifically, the present study investigated the effects of unit price descriptions (descriptions given or not given to participants) and unit price composition (either FR or VR response requirements) on the consumption of money as a reinforcer with humans. Furthermore, the present study also investigated unit price sequence effects in a limited manner by examining an alternate sequence for one of the conditions. Participants were assigned to one of 6 groups of 3, who were either exposed to FR or VR based unit prices and either received or did not receive unit price descriptions. Only participants exposed to the FR based unit prices encountered different presentation orders. The experimental task consisted of using a computer to solve multiplication problems ranging from 1 x 1 to 10 x 10 in exchange for money (similar to Viken, 1999). All of the participants

were exposed to the same five unit prices, although one additional unit price was used with some of the participants.

CHAPTER 2

METHOD

Participants and Setting

Eighteen undergraduate college students from the University of North Texas, ranging from 18-27 years of age, participated in this experiment. In total, 9 participants were female and 9 were male. Participants S3, S5, S7, S9, S11, S13, S14, S15, and S18 were female, and participants S1, S2, S4, S6, S8, S10, S12, S16, and S17 were male. Each of the participants was randomly assigned to one of six conditions with a total of 3 participants in each condition. The participants were recruited from introductory behavior analysis classes, newspaper advertisements, and flyers posted around the University campus. All participants completed pre-screening questionnaires to determine if they possessed any visual or motor impairments which would interfere with their performance. The participants were also exposed to all of the multiplication problems used in the experiment, and were required to meet a minimum of 12 problems correct per min on a 2-min timed test on these problems. One participant did not meet the requirement and did not participate in the experiment. One other participant quit the experiment without notification and her data were not included in this experiment. Participants could earn from $0.00 to $6.00 in 5-cent increments depending on their performance in the session, and were paid the amount earned at the end of the session. The participants also received a $25.00 bonus at the completion of the experiment.

The experiment took place in a University laboratory which contained a table with a computer, computer monitor, keyboard, mouse, and a chair. The participants were alone in the room during the sessions, and were instructed not to bring any materials inside the room.

Apparatus

The apparatus consisted of an Intel Pentium-based 200 MHz IBM-compatible computer, monitor, keyboard, and mouse. A computer program, written in Visual Basic ®, served to present multiplication problems ranging from 1 x 1 to 10 x 10. The problems appeared in 150 pt Comic Sans Serif font on a grey colored screen with a space at the bottom used to display what was typed by the participants (i.e., the answers to the problems). Each multiplication problem was randomly selected, without replacement, from a list containing every multiplication problem between 1 x 1 and 10 x 10. When each problem had been presented one time, the program reset and began selecting from the entire list. Answers to the problems were entered using the numeric keypad or the numbers on the top part of the computer keyboard. If the participant entered the correct answer, the next problem appeared. If the participant entered the incorrect answer, the text color of the math problem changed from black to red and remained on the screen until a correct answer was provided.

At the completion of each response requirement, the program presented a pre-recorded sound clip of a human voice stating, "5 cents". If the participant remained in the session and earned the total amount possible, a screen appeared at the completion of that session showing the amount earned in cents. The participant could terminate the session at any time. Pressing the "Q" button on the keyboard at any time during the session automatically

terminated the session and the same screen appeared showing the total amount earned up to that point in the session, in cents.

Dependent Variable

The dependent variables consisted of the total consumption of money at each unit price, the total amount of responding at each unit price, response rates per session, and session durations.

Independent Variable

The independent variables consisted of the unit price structure, the descriptions of the unit prices, and the presentation order of the unit prices.

Procedure

Participants were exposed to a pre-screening and training session followed by a minimum of five experimental sessions. Aside from the pre-screening combined with the training session, only one experimental session was conducted per day requiring a minimum of six days to complete the experiment. In each session, the participants could earn money by solving math problems. The target response consisted of entering the correct answer using either the numeric keypad or the numbers at the top of the keyboard, followed by the enter key. Correct answers counted towards the response requirement for that session. Incorrect answers were not penalized, but did not count towards the response requirement. Each completed response requirement earned 5 cents until the maximum of $6.00 was reached or the session was terminated by the participant. In most behavioral economic experiments, participants do not have an upper limit on consumption. Because this experiment involves the

use of money as a reinforcer, however, allowing participants unlimited earnings was not feasible and the limit was set at $6.00. Depending on the UP in the particular session, different numbers of problems were required to earn the 5 cents and reach the maximum. All of the participants were exposed to the same unit prices: UP 1, UP 3, UP 5, UP 7, and UP 10, but some were exposed to UP 15. The composition of the unit prices as well as the order in which they were presented depended upon the experimental group. At least one exposure to each unit price was required to complete the experiment, and in most cases a minimum of one replication occurred at each unit price. In some cases, time constraints or participants quitting the experiment prevented replications at each unit price. For some participants, exposures to particular unit prices were replicated a third time.

Session length was always determined by the participants. During each session, the participant could take as long as needed to earn the maximum amount or had the option to terminate the session at any point. Because an upper limit was set on the amount a participant could earn, the session length was not limited. If the session length did have a limit, it is possible that the session time could elapse while the participant was still responding and artificially produce a decrease in consumption. The participants were also allowed to take breaks of unspecified length at any point throughout the session. At the end of each session, the participants recorded the amount earned on a payment log and received full payment. At the completion of the experiment, each participant received the $25.00 bonus and was fully debriefed.

Pre-screening

During the initial meeting with each participant, the experimenter read the following statements out loud:

> The experiment you are about to participate in involves solving multiplication problems ranging from 1 x 1 to 10 x 10. Only one session will be conducted per day, and the total number of sessions will be around 15. You will earn a $25.00 bonus when you complete all of the sessions. Sessions must be scheduled for a time that will not conflict with other activities. For example, sessions should not be scheduled directly before a meeting or class time.

The participants were then asked to fill out several forms including a schedule and screening questions which inquired about possible handicaps that would interfere with participation in the experiment. No participants were dismissed based on the results of these questions. The participants were also required to complete a worksheet with every multiplication problem ranging from 1 x 1 to 10 x 10 with no more than 5 errors, as well as correctly solve the same problems at a rate of 12 per min on a 2-min timed test. Only 1 participant did not meet these requirements and was not used in the experiment. The participants were then given the informed consent form to read and sign.

Training

During this session the participants practiced terminating the session by earning the maximum amount possible as well as actively terminating the session by pressing the "Q" button. Before the participants arrived, the maximum earning value for the session was set to

25 cents. The UP value was set to 1 so that either every five problems earned 5 cents or an average of five problems earned 5 cents depending upon which group the participant was in. The participant entered the experimental room, sat down in front of the computer, and was given a copy of the general experimental instructions. The participant was then instructed to follow along as the experimenter read the following instructions out loud:

> "In this experiment, you will have the opportunity to earn up to $6.00 every session. The way you can earn money is to work by solving math problems. The purpose of this study is to investigate choice. In each session, you will be able to choose to work as little or as much as you want. You can solve as few or as many math problems as you choose. If you choose to solve math problems, type in the answer using the numeric keypad and press the enter key. If the answer is correct, another problem will presented on the screen. If the answer is incorrect, the problem will turn red, and will remain on the screen until a correct answer is provided. Incorrect responses will NOT count against you in any way. While solving the problems, you may notice a sound periodically informing you of the amount of money you have just earned. The computer will keep a running total of your earnings throughout each session. If you choose not to solve math problems, at any time after the session begins you may press the "Q" button on the keyboard followed by the enter key and the session will terminate. There is no penalty for pressing the "Q" button at any point throughout the session and you will be paid the amount of money you

have earned up to that point. You may also take short breaks at any point throughout the session to use the bathroom or to get a drink of water. Do not press "Q" if you want to take a break; you may leave a problem presented on the screen until you return. When the session ends, a screen will appear telling you how much money you have earned and you may go inform the experimenter that you have finished. Please remember, there is no right or wrong way to respond. It makes no difference to the experimenter what you choose to do. The number of math problems you choose to solve is entirely up to you."

The participant was then told that the instructions would remain posted on the wall for the duration of the experiment. The experimenter then read these additional instructions out loud:

"The purpose of this session is to familiarize you with the experiment. In this session you will earn 25 cents. Normally, you will be able to earn up to $6.00. When you earn the 25 cents the session will terminate. At this point, exit the room and find the experimenter. Please begin when I exit the room."

After the session was completed, the participant was asked to exit the room for a few minutes. The session was then reset to the same values and the participant was asked to enter the room again. When the participant was seated, the experimenter read these instructions out loud:

"Now I would like you to practice ending the session. When the first problem is presented, terminate the session. You may refer to the instructions if necessary. I will remain in the room during this session."

Any questions during this session were answered by repeating the relevant parts of the instructions. At the completion of this session, the participant recorded the amount earned (25 cents) on the payment log and received the 25 cents.

FR Groups (FR)

The unit prices in this condition were composed using FR response requirements with the standard reinforcer magnitude of 5 cents. For example, a UP 1 was composed using the ratio of 5 responses over 5 cents. In this case every 5 responses (FR-5) earned 5 cents requiring a total of 600 responses to earn the maximum of $6.00. A UP 3 was composed of 15 responses over 5 cents in which every 15 responses earned 5 cents requiring a total of 1,800 responses to earn the $6.00. UP 5 was composed of an FR-25 requiring 3,000 responses needed to earn the $6.00. UP 7 was composed of an FR-35 requiring 4,200 responses to earn the $6.00. UP 10 was composed of an FR-50 requiring 6,000 responses to earn the $6.00.

VR Groups (VR)

The unit prices in this condition were composed using VR response requirements over the same reinforcer magnitude of 5 cents. In this case, the response requirements used were averages which slightly affected the total number of responses required to earn the $6.00 at every price. The required responses varied from those in the FR groups by the number of the

UP value (e.g., 1, 3, 5, 7, 10, or 15) for each session. For example, a UP 1 was composed using the ratio of an average of 5 responses over 5 cents, but the required responses could vary between one number above and below the typical requirement. In this case, either 599, 600, or 601 total responses could be required to earn the $6.00. Under UP 3, 1800 responses were typically required to earn $6.00. For the VR group, the total responses could range from 1797 to 1803 because the UP value was 3. This same pattern occurred for all of the unit prices; total responses to earn the maximum amount varied by the same number as the UP value.

A rectangular distribution was utilized to generate the range of values comprising the VR schedules by calculating 20% above and below the VR value. The computer program then randomly selected each value in the range without replacement. When every value in the range was used one time, the program once again began selecting from the entire list. For example, to generate a rectangular distribution for a VR-5 schedule, 20% of the schedule value was calculated and then added and subtracted from the schedule value to generate the highest and lowest values of the range respectively. In this case, 20% of 5 is equal to1, so the range of a VR-5 schedule was 4-6. During a UP 1 session, the unit price was composed of a VR-5 response requirement and a reinforcer magnitude of 5 cents. The reinforcers in this session were delivered either after 4, 5, or 6 math problems were solved correctly. After three reinforcer deliveries occurred (i.e., all the values in the range were used) the program began selecting again from the range of 4, 5, or 6. A UP 3 was composed of a VR 15 with the response requirements ranging between 12-18 problems. A UP 5 was composed of a VR-25

with a range of 20-30. A UP 7 was composed of a VR 35 with a range of 28-42. A UP 10 was composed of a VR-50 with a range of 40-60. A UP 15 was composed of a VR-75 with a range of 60-90.

Creating the rectangular distributions in this way produced variable response requirements, and also produced less overlap of the values used in the ranges at each UP. For example, no overlap occurred between the range of values used in UP 1 and UP 3 or between UP 3 and UP 5. Three values overlapped between UP 5 and UP 7 and also between UP 7 and UP 10. Only one value overlapped between UP 10 and UP 15. Keeping overlap of the ranges between prices at a minimum was a concern in that too much overlap might make the changes between prices less discriminable for the participants.

No UP Descriptions (ND)

Before the first experimental session the experimenter read the general instructions out loud one final time. Also before the first session, as well as before the remainder of the sessions in this condition, the experimenter read the following daily instructions out loud:

> "The instructions are posted on the wall. Remember you can solve as few or as many math problems as you choose."

UP Descriptions (D)

As in the no-description condition, the general instructions were read a final time before the first session. The same daily instructions were read during the first session and the remaining sessions, as well as an additional instruction that consisted of a statement describing the particular UP in effect for each session. Depending on which group the participant was in,

the description was either in terms of an FR response requirement or a VR response requirement. For the FR group in this condition, the experimenter read the following instructions out loud:

> "The instructions are posted on the wall. In today's session you will earn 5 cents for every [X] number of problems you solve. Remember, you can solve as few or as many math problems as you choose."

The description changed according to the particular UP in effect for each session. For example, in a UP 5 session, the description read, "In today's session you will earn 5 cents for every 25 problems you solve." In a UP 10 session, the description read, "In today's session, you will earn 5 cents for every 50 problems you solve." The VR group in this condition were read the same daily instructions with a different description. In this case, the experimenter read the following instructions out loud:

> "The instructions are posted on the wall. On average, for every [X] problems you solve in today's session, you will earn 5 cents. Remember, you can solve as few or as many math problems as you choose."

As in all of the first sessions, the response requirement was set at five, and the following example was read out loud by the experimenter only during the first session:

> "For example, in today's session sometimes you may have to solve 4 problems to earn 5 cents, sometimes you may have to solve 6 problems to earn 5 cents, and other times it may take a different number of problems to earn 5 cents, but it will average out to 5 problems per 5 cents. Do you understand?"

Questions were answered by repeating the relevant parts of the instructions or by repeating the example. The description changed according to the UP in effect for that particular session and no other examples were given after the first session.

UP sequence

Table 1 shows the sequences of unit prices used for all of the participants. The first FR group contacted the UPs in the following order: 1, 3, 7, 5, 1, 10, and the replications occurred in the following order: 5, 3, 7, 10. The replication of UP 1 occurred before exposure to all of the UPs. For the VR group, the unit prices were inadvertently presented in a different order: 1, 3, 7, 5, 10, with the replications occurring in the same order as well. As a result, it would not be possible to determine which variable led to any differences between the FR and VR groups. In order to account for this issue, an additional FR group was added and exposed to the same sequence of UPs and replications as in the VR group. Taking this additional step allowed for a clear comparison between the FR and VR groups as well as allowed for a comparison between the FR groups with different UP sequences. To make comparisons between groups easier, the groups are not presented chronologically and the first UP sequence is referred to as FR#2. Additionally, the VR participants were exposed to a higher UP (UP 15), due to the fact that their consumption levels at UP 10 were above levels seen previously.

Design

This study utilized a within-subject parametric design with participants in groups arranged factorially to enable comparisons between FR versus VR unit price structures, unit price descriptions and no-descriptions, and FR sequences. The groups and conditions were

combined as follows: (a) VR-ND, (b) VR-D, (c) FR-ND, (d) FR-D, (e) FR#2-ND, (f) FR-#2-D.

CHAPTER 3

RESULTS

The data were analyzed in terms of demand and work output functions. Demand functions are shown by plotting consumption against increasing unit prices in logarithmic coordinates. The resulting shape of the demand function, as well as the slope between prices, shows the relationship between the two variables. Elasticity coefficients, calculated according to Samuelson and Nordhaus (1985), show whether demand was elastic or inelastic between particular prices. According to this formula, elastic demand is shown by coefficients greater than or equal to 1.0 and inelastic demand is shown by coefficients less than 1.0. Furthermore, the magnitude of the elasticity coefficient relates to the level of elasticity, with larger numbers indicating more elastic demand.

Work output functions are shown by plotting total amount of responding against increasing unit prices in logarithmic coordinates. The shape of this function shows how the total amount of responding changes as unit price increases. Typically, a bitonic function is obtained resulting from defense of consumption up to the point at which demand becomes elastic. The peak of the work output always corresponds to the prices at which demand becomes elastic.

The rate of responding in each session was also calculated for each participant in terms of the number of problems solved per minute. Additionally, session duration was calculated for each participant to check for any "self-imposed" time constraints. Any breaks during a session

in which the participant left the room were not included in this calculation. If session durations are flat across unit prices, it suggests that the participant may have been allocating a fixed amount of time to each session. Furthermore, if the sessions were consistently terminated after the same duration (e.g., 30 min), an artificial reduction in consumption across sessions in which the unit price increased would result. Specific instances of when this may have occurred will be discussed. Finally, differences in consumption between first and second exposures to the same unit prices, when possible, were also investigated to check for any consistent patterns.

Overall, three general findings occurred across all participants in terms of rate of responding in each session, demand elasticity, and work output. Figures 1-3 show the rate of responding in each session for all participants separated by group. All of the participants showed increases in the rate of responding across sessions. Some participants increased at a faster rate than others, but a general increase was evident in all cases. For 2 participants, S4 and S6 in the VR-D group, there are some sessions during which the rate of responding decreased. S4 shows a decrease in rate during sessions 3, 4, and 5 (UP 7, 5, and 10 respectively) followed by a large increase in rate. During replications at those same prices (sessions 8, 9, and 10), however, an increasing trend was apparent. S6 showed an increasing trend during the first four sessions followed by a large decrease in rate during the last completed session. No consistent differences in the rates of responding were found between groups, however, the highest rates in responding were produced by participants S2 and S3 from the VR-ND group.

Figures 4-21 show the demand and work output functions for all of the participants. The actual amounts earned and number of responses emitted are shown in Tables 2-4. All of the participants showed a decrease in consumption as a function of increases in unit price. Furthermore, the demand curves for all of the participants showed mixed elasticity. Differences at the points at which the curves became elastic, the overall level of consumption, and the magnitude of elasticity within and between groups will be discussed below. In terms of work output, almost all of the participants showed bitonic functions with peaks in responding corresponding to points of elasticity. Specific instances where a bitonic function was not obtained as well as oddly shaped work output functions will be discussed.

VR-ND

Figures 4-6 show the demand and work output functions for the 3 participants in the VR-ND group. Overall, the demand curves for these 3 participants were relatively inelastic. The demand curve for participant S1, shown in Figure 4, became elastic between UP 5 and 7, and remained elastic between UPs 7 and 10, and 10 and 15. A second replication was conducted at UP 7 because the first replication seemed to be unusually low. The work output for this participant showed a bitonic function with the peak in total responding at UP 5, corresponding to the point at which demand became elastic. Participant S2's demand curve, shown in Figure 5, only became elastic between UP 10 and 15 and showed a bitonic work output function with the peak in responding occurring at UP 10. The demand curve for participant S3, shown in Figure 6, became elastic between UP 7 and 10, and remained elastic at the higher prices. Work output for participant S3 showed a bitonic function with the peak

occurring at UP 7. The session durations for participants S1, S2, and S3 are displayed in Figure 25. Durations during first exposures were bitonic, paralleling the work output functions. Second exposure durations were most often lower than first exposure durations at the same price.

VR-D

Figures 7-9 show the demand and work output functions for the 3 participants in the VR-D group. The elasticity of demand was greater for these 3 participants than for the participants in the VR-ND group. For participant S4, shown in Figure 7, demand became elastic between UP 5 and 7 and remained elastic at higher prices, similar to participant S1 in the VR-ND group. All 3 of the participants in this group, however, were elastic between 7 and 10 whereas only 2 of the 3 participants in the VR-ND group were elastic between these prices. All of the participants in both groups (who were exposed to UP 15) showed elastic demand between UP 10 and 15.

The average level of consumption at UP 5, 7, 10 and 15 was lower for all 3 participants in the VR-D group than for the VR-ND group. Differences in consumption levels were also compared using statistical tests with an alpha level of .05. A repeated-measures analysis of variance (ANOVA) showed the overall differences between groups to be statistically significant, $F(1, 4) = 14.39$, $p = .0192$. An ANOVA comparing consumption levels at each price revealed these differences to be statistically significant at: UP 5, $F(1, 4) = 7.67$, $p = .0504$; UP 7, $F(1, 4) = 11.36$, $p = .0280$; UP 10, $F(1, 4) = 9.63$, $p = .0361$; and UP 15, $F(1, 4) = 17.00$, $p = .0259$. These results support visually apparent differences in

average consumption levels between these 2 groups shown in the group summary graph, Figure 22.

As a result of having large decreases in consumption at these higher prices, the magnitudes of the elasticity coefficients are higher for all of the participants in the VR-D group than for the VR-ND group. Table 5 shows the elasticity coefficients for all of the participants in each group. Of the cells that are shaded (indicating elastic demand) for the VR groups, the elasticity coefficients for the VR-D group between UPs 5 and 7, 7 and 10, and 10 and 15, are higher in every case indicating more elastic demand.

All 3 of the participants in this group showed bitonic work output functions with peaks corresponding to the points at which their demand curves became elastic. Analysis of the session durations for these participants, shown in Figure 26, did not show any indication that the sessions had been constrained by a self-imposed time limit. For participant S5 (see Figure 8), a second replication was conducted at UP 7 because consumption was initially lower at UP 5. Only one exposure to each unit price occurred for participant S6 (see Figure 9), due to the fact that the semester ended after the first-exposure to the price sequence. Furthermore, this participant was not exposed to UP 15 because of the low level of consumption that occurred at UP 10.

FR-ND

Figures 10-12 show the demand and work output functions for the participants in the FR-ND group. For 2 out of 3 of these participants (S7 and S9, Figures 10 and 12 respectively), demand became elastic between UP 5 and 7. For participant S7 demand

remained elastic between 7 and 10; however, for participant S9 demand reverted back to being inelastic. The demand curve for participant S8, shown in Figure 11, became elastic between 7 and 10. Because the average level of consumption was lower at UP 5 than at UP 7 for this participant, the elasticity coefficient between these two prices was negative.

The work outputs for participant S8 showed a bitonic function with a peak at UP 7 where demand became elastic. Participant S9 had an oddly shaped work output function due to the fact that demand changed from elastic to inelastic after elastic demand had been shown at earlier prices. The peak in the work output at UP 7 for this participant corresponded to the point at which demand became elastic. However, the inelastic demand between UP 7 and 10 resulted in a slight increase between those two prices after the peak. The work output for participant S7 was relatively flat with only a very slight peak in responding at UP 5. Aside from the responding at UP 1, this participant emitted nearly the same number of responses across the other unit prices.

When looking at the session durations for participant S7, shown in the top graph of Figure 27, it appears as though the participant may have been constraining the sessions by allotting approximately the same amount of time for each session. Limiting the sessions in this way would produce a decrease in consumption across prices because the same number of responses occurring at each unit price would yield less consumption at higher prices. This would also produce an almost entirely flat work output function. In this case, however, there was a slight increase in the total amount of responding followed by a decrease after the peak. This slight increase was likely due to the fact that the rate of responding for this participant

increased as the sessions progressed (see Figure 2). Therefore, even though approximately the same amount of time was allowed for each session, the increase in the rate of responding allowed higher levels of consumption at the higher prices, preventing the work output function from being completely flat. The session durations for participants S8 and S9, also shown in Figure 27, did not show any systematic similarities across sessions, except for the second exposure at UP 5 and UP 7 for participant S9. This only occurred for these two sessions, and did not seem to have a visible effect on the work output for this participant.

FR-D

Figures 13-15 show the demand and work output functions for the participants in the FR-D group. Some slight differences were found between these participants and the participants in the FR-ND group but, overall, the demand for one group was not clearly more elastic than the other. The demand for 1 participant in the FR-D group, S10 (shown in Figure 13), became elastic between UP 3 and 5 and remained elastic at higher prices. None of the participants in the FR-ND group showed elastic demand between UP 3 and 5. Both groups showed elastic demand between UP 5 and 7 with 2 participants, and 3 participants in the FR-D group showed elastic demand between UP 7 and 10, whereas 2 of the 3 participants in the FR-ND group showed elastic demand between these prices. The participant in the FR-ND group who did not show elastic demand between UP 7 and 10, however, had previously shown elasticity at lower prices.

Figure 23 shows the average consumption for all of the participants in both the FR-ND and the FR-D group. No consistent differences in consumption level were shown at UP 5 or 7

between participants in both FR groups: Two of the 3 participants in the FR-ND group had higher levels of consumption than any of the FR-D participants at UP 10. According to a repeated-measures ANOVA, the overall differences in consumption levels were not statistically significant, and ANOVAs comparing the differences in consumption level at each price were also not statistically significant.

The magnitude of the elasticity coefficients between UP 5 and 7, shown in the middle portion of Table 5, did not show consistent differences between the FR-ND and FR-D groups. However, between UP 7 and 10, the coefficients for the FR-D participants were higher than for the FR-ND participants, suggesting greater elasticity for the FR-D group.

The work output functions for these participants were all bitonic, with peaks corresponding to the points of demand elasticity. The session durations for these participants are shown in Figure 28, and all seem to vary at different prices indicating that the participants were not likely constraining the sessions.

Participant S10 discontinued participation in the experiment prematurely, and did not complete replications at UP 5 and UP 10. A second replication at UP 7 was conducted for participant S11 due to the fact that consumption levels at UP 5 were lower than at UP 7 during the replication. Consumption on the second replication at UP 7 was still higher than at UP 5, resulting in a negative elasticity coefficient between these prices.

FR#2-ND

Figures 16-18 show the demand and work output functions for the participants in the FR#2-ND group. For 1 of these participants, S15 (shown in Figure 18), demand became

elastic between UP 1 and 3, and the only inelastic portion of the demand curve for this participant occurred between UP 5 and 7 when consumption levels were extremely low. Participant S13's demand, shown in Figure 16, became elastic between UP 3 and 5, was inelastic between UP 5 and 7, and was elastic again between UP 7 and 10. For both participants S13 and S15, demand reverted back to inelastic between UP 5 and 7. Only 1 participant (S14 shown in Figure 17), became elastic between UP 5 and 7 and remained elastic between higher prices.

The work output for participant S14 showed a bitonic function with a peak in responding at UP 5 where demand became elastic. Participant S13's work output function showed two peaks in responding due to the fact that demand became elastic at two points along the curve, and both peaks correspond to the prices at which demand became elastic. For participant S15, an overall bitonic function was not obtained in that consumption was not defended at the lower prices (i.e., between UP 1 and 3). The highest points of responding at UP 3 and UP 7 do correspond to the points at which demand became elastic, but there is no increase between UP 1 and 3 because the same number of responses were emitted at each price.

The session durations for these participants are shown in Figure 29. For all of the participants, even S15, there are no systematic similarities across session durations. The failure to obtain an overall bitonic function for participant S15 was not likely due to any constraining of the session duration, and was probably more a function of the overall low levels of consumption.

FR#2-D

Figures 19-21 show the demand and work output functions for the participants in the FR#2-D group. Both the FR#2-ND group and the FR#2-D group were similar, except for S15, in terms of when the demand for the participants in each group became elastic, the levels of consumption at the higher prices, and the magnitude of the elasticity coefficients. The demand curve for participant S15 showed early and steep decreases in consumption which did not seem to be representative of the demand curves for the other participants in the FR#2-ND group. None of the participants in the FR#2 group had demand curves that became elastic between UP 1 and 3, whereas one of the participants in the FR#2-ND group showed elasticity in this price range. The demand for 2 out of the 3 participants in this group (S16 and S17, Figures 19 and 20 respectively), became elastic between UP 3 and 5. Both groups had 2 participants who displayed elastic demand between UP 3 and 5. Between UP 5 and 7, demand remained elastic for participant S16 and became elastic for participant S18 (see Figure 21), whereas only1 participant in the FR#2-ND group showed elastic demand between those prices. Between UP 7 and 10, the demand for all 3 participants was elastic as in the FR#2-ND group.

Figure 24 shows the average consumption for the participants in the FR#2-ND and FR#2-D conditions. Comparison at the higher prices, UPs 5, 7 and 10, between these 2 groups did not show any consistent differences in consumption, with the exception of 1 participant. Participant S15 had unusually low levels of consumption, but all of the other participants had very similar consumption levels. The range of consumption levels that occurred

in the FR#2-D condition fell in the same range as the values generated by the participants in the FR#2-ND condition; a repeated-measures ANOVA failed to find any statistically significant differences in the overall consumption levels between the 2 groups, and price to price comparisons using at UPs 5, 7, and 10 did not show any statistically significant differences according to an ANOVA. Elasticity coefficients, shown in the lower portion of Table 5, revealed no consistent differences between these two conditions.

The work output for participant S16 showed a bitonic function with a slight peak at UP 3, where demand became elastic. The somewhat flat portion of the function between UP 3 and 5 corresponds to the fact that demand between those two prices was only slightly elastic (see Figure 19). For both participants S17 and S18, the work output functions appeared flat. Participant S17's work output function has two peaks corresponding to the two places on the demand curve where elasticity was shown, but aside from the drop at UP 5, it was relatively flat. The work output for participant S18 only had a slight peak at UP 5 but was otherwise relatively flat as well.

Analysis of the session durations for participants S17 and S18, shown in Figure 30, showed some consistencies across prices which may indicate that these participants were constraining the sessions leading to the flat work output functions. This effect was not as pronounced for participant S17 as it was for participant S18. Consistencies in session duration were in fact, more apparent for participant S18 especially in the second exposures to UPs 3, 5, 7, and 10. Both of these participants also showed increases in the rate of responding across

sessions (see Figure 3), which is likely responsible for the slightly bitonic functions that did appear.

VR-ND and FR-ND

Differences between the 2 VR groups require that they be separately compared to the FR groups to examine VR-FR similarities and differences. The demand curves for the participants in these groups are shown in the top graphs of Figures 22 (VR-ND) and 23 (FR-ND). Based on visual inspection and ANOVA tests, the data indicate a small but consistent difference in consumption levels between these 2 groups. Two out of 3 FR-ND participants (S7 and S9) showed elastic demand between UP 5 and 7, compared to only1 participant (S1) in the VR-ND group. Both groups had 2 participants (S1 and S3 from the VR-ND group and S7 and S9 from the FR-ND group) that showed elastic demand between UP 7 and 10. One participant (S2) in the VR-ND group had not yet shown elastic demand between UP 7 and 10, and participant S9 from the FR-ND group did not show elastic demand between those prices either. The difference between these two participants is that participant S9 had previously shown elastic demand and participant S2 had not previously shown elastic demand between UP 7 and 10.

Comparison of the overall levels of consumption did not reveal any statistically significant differences according to a repeated-measures ANOVA; however, at UP 5 all of the participants in the VR-ND group had higher consumption levels than all of the participants in the FR-ND group, and an ANOVA showed this difference to be statistically significant, $F(1, 4) = 14.22$, $p = .0196$. At UP 7, consumption levels were mixed with no statistically significant

differences. At UP 10, consumption levels were higher for 2 out of the 3 VR-ND participants (S2 and S3), but an ANOVA comparing consumption levels for both groups at UP 10 only approached statistical significance, $F(1, 4) = 5.02$, $p = .0885$.

Although none of the participants in either group showed elastic demand between UP 3 and 5 (see Table 5), the elasticity coefficients that were produced in the FR-ND group were consistently higher, which relates to the differences in consumption that occurred between these groups. No consistent differences in magnitude appeared between UP 5 and 7; however, between UP 7 and 10, both participants whose demand was elastic in the FR-ND group (S7 and S8) had higher elasticity coefficients than the 2 participants in the VR-ND group (S1 and S3).

VR-D and FR-D

The demand curves for these participants are shown in the bottom graphs of Figures 22 (VR-D), and 23 (FR-D). The consistent difference between these 2 groups was in terms of the point at which the participants became elastic. The data indicated that the demand curves for the FR-D participants became elastic earlier than VR-D participants. One of the participants in the FR-D group (S10) showed elastic demand between UP 3 and 5 whereas none of the participants in the VR-D showed elastic demand between these prices. Furthermore, 2 participants in the FR-D group (S10 and S12) showed elastic demand between UP 5 and 7; 1 had remained elastic and 1 became elastic between these prices. Only one VR-D participant (S4) showed elastic demand between UP 5 and 7, and this participant was becoming elastic for the first time. All 3 participants in both groups showed elastic demand between UP 7 and 10;

however, the demand for 2 of the VR-D participants (S5 and S6) was becoming elastic for the first time, and the demand for only one FR-D participant (S18) was becoming elastic for the first time.

Mixed differences in the level of consumption for the participants in both groups occurred at UPs 5, 7 and 10; the consumption levels in either group were not consistently higher or lower at any price. Consistent with visual inspection, a repeated-measures ANOVA comparing the overall consumption levels and an ANOVA comparing consumption levels at each price, did not show any statistically significant differences.

Differences in the magnitude of the elasticity coefficients (see Table 5) were apparent between UP 5 and 7 in that the one VR-D participant (S4) who showed elastic demand between these prices had a higher elasticity coefficient than both FR-D participants (S16 and S18) who showed elastic demand. No consistent differences in magnitude were apparent between UP 7 and 10, but the highest elasticity coefficient (5.07) for any participant between any two prices was produced by participant S6 in the VR-D group.

FR-ND and FR#2-ND

These groups were compared to examine whether there were any possible effects of the two different sequences of unit prices. The demand curves for these participants are shown in the top graphs of Figures 23 (FR-ND) and 24 (FR#2-ND). Comparison of these 2 groups showed differences in the point at which the demand for the participants in each group became elastic, with FR#2-ND participants becoming elastic earlier, but no consistent differences in terms of consumption levels or the magnitudes of the elasticity coefficients. The demand for 1

participant (S15) in the FR#2-ND group became elastic between UP 1 and 3, and none of the participants in the FR-ND group showed elastic demand between these prices. Between UP 3 and 5, 2 of the 3 FR#2-ND participants (S13 and S15) showed elastic demand whereas the demand for the 3 participants in the FR-ND had not yet become elastic. The demand for one participant (S14) in the FR#2-ND group became elastic between UP 5 and 7, compared to the FR-ND group in which the demand for 2 of the 3 participants (S7 and S9) became elastic. The demand for the participants in the FR-ND group, however, was becoming elastic for the first time whereas the 2 participants in the FR#2-ND group (S13 and S15), whose demand was not elastic between these prices, had shown elastic demand at earlier prices. All 3 FR#2-ND participants and 2 of the FR-ND participants (S7 and S8) showed elastic demand between UP 7 and 10. The 1 FR-ND participant (S9) who did not show elastic demand between UP 7 and 10 had previously shown elastic demand, and the demand for participant S8 became elastic for the first time between these prices.

No consistent differences were visually apparent in the consumption levels between these 2 groups at UPs 5, 7 and 10, with the exception of participant S15, and either ANOVA test did not reveal any statistically significant differences. Although participant S15 had a lower level of consumption than all of the other participants in either of these 2 groups, the fact that the other participants' consumption levels were so similar somewhat canceled out the difference both visually and statistically.

Between UP 5 and 7, no consistent differences in the magnitudes of the elasticity coefficients (see Table 5) were found between the 2 groups, but between UP 7 and 10, two

out of the three elasticity coefficients were larger in the FR#2-ND group than in the FR-ND group.

FR-D and FR#2-D

The demand curves for these participants are shown in the lower graphs of Figures 23 (FR-D) and 24 (FR#2-D) and each participant's elasticity coefficients are presented in Table 5. For these 2 groups, the data showed a slight indication that the demand curves for FR#2-D group were more elastic than the FR-D group in terms of the point of elasticity and in the levels of consumption. The demand for 2 out of 3 participants (S16 and S17) in the FR#2-D group became elastic between UP 3 and 5 compared to only1 participant (S10) in the FR-D group. Two participants from both groups (S16 and S17 in the FR#2-D group and S10 and S12 in the FR-D group) showed elastic demand between UP 5 and 7, but the one participant in the FR#2 group (S17) who did not show elastic demand between these prices had shown elastic demand between UP 3 and 5. Between UP 7 and 10, all of the participants in both groups showed elastic demand.

When looking at the overall level of consumption between the 2 groups, no visual or statistically significant differences, according to a repeated-measures ANOVA, were found. In terms of the level of consumption at each price, there was a visually apparent difference at UP 3. The levels of consumption at UP 3 were higher in all cases for the FR-D participants than for the FR#2-D participants and an ANOVA showed this difference to be statistically significant, $F(1, 4) = 24.17$, $p = .0079$. At UP 5, the level of consumption was higher for 2 of the 3 FR-D participants, but was not statistically significant. At UPs 7 and 10, the levels of

consumption were mixed between the 2 groups, and no visual or statistically significant differences were found.

In terms of the magnitudes of the elasticity coefficients, the coefficients produced by the participants in the FR-D group were higher in all cases between UP 3 and 5, and between UP 7 and 10 than those produced by the FR#2-D group. Between UP 5 and 7, the magnitudes of the coefficients were mixed between the groups. Even though neither group had any participants who showed elastic demand between UP 1-3, the coefficients in the FR#2-D group are all higher than those in the FR-D group (indicating lower levels of consumption at UP 3) which corresponds to the statistically significant difference found in consumption between the 2 groups at UP 3.

Because no strong differences were found either within the FR group or the FR#2 group as a function of unit price descriptions, a pooled comparison between the entire FR and FR#2 groups was conducted. Although this comparison did not yield previously unknown information, it highlighted the aspects in which these groups differed, which was the point at which the demand curves for the participants in each group first became elastic. One out of 6 participants (S15) in the FR#2 group showed elastic demand for the first time between UP 1 and 3, with no participants showing elastic demand between those prices in the FR group. Between UP 3 and 5, 4 out of 6 FR#2 participants (S13, S15, S16, and S17) showed elastic demand with 3 of those participants showing elastic demand for the first time, compared to only 1 participant (S10) in the FR group. Between UP 5 and 7, the FR group had 3 participants (S7, S9, and S12) becoming elastic for the first time and 1 participant (S10) remaining elastic.

In the FR#2 group, the 3 participants (S13, S15, and S17) who did not show elastic demand had already shown elastic demand at earlier prices. All 6 participants in the FR#2 group showed elastic demand between UP 7 and 10, and had all previously shown elastic demand. In the FR group, 5 of the participants (S7, S8, S10, S11, S12) showed elastic demand, with 2 of those participants (S8 and S11) showing elasticity for the first time. The participant who did not show elastic demand (S9) had previously shown elasticity between UP 5 and 7.

The only statistically significant difference in level of consumption between the 2 groups was found at UP 3, $F(1, 10) = 6.14$, $p = 0.326$. This difference is also apparent when looking at all of the elasticity coefficients between UP 1 and 3 between the groups (see Table 5). With the exception of S7, all of the elasticity coefficients for the FR group between UP 1 and 3 are zero, indicating no change in consumption. Only one FR#2 participant had an elasticity coefficient of zero between these two prices. Other differences in the magnitude of the elasticity coefficients were mixed between the 2 groups, however, between UP 7 and 10, 2 out of 6 coefficients were larger for the FR group than the FR#2 group.

VR-ND and FR#2-ND

The demand curves for these participants are shown in the top graphs of Figures 22 (VR-ND) and 24 (FR#2-ND), and the elasticity coefficients are shown in Table 5. Although any differences between these 2 groups may be confounded by sequence differences, comparisons were made. Consistent differences were found between these groups in terms of the point at which the participants in each group showed elasticity for the first time, levels of consumption, and the magnitudes of the elasticity coefficients, indicating that the demand for the

participants in the FR#2-ND group was much more elastic than for the participants in the VR-ND group. For the FR#2-ND group, 1 participant (S15) showed elastic demand for the first time between UP 1 and 3 and remained elastic between UP 3 and 5, where another FR#2-ND participant (S13) showed elasticity for the first time. No elastic demand occurred for any of the VR-ND participants between either UP 1 and 3, or UP 3 and 5. Each group showed 1 participant's demand (S1 in the VR-ND group and S13 in the FR#2-ND group) becoming elastic for the first time between UP 5 and 7, however, this was the first VR-ND participant to show elastic demand. All 3 FR#2-ND participants showed elastic demand between UP 7 and 10 and had all previously shown elastic demand, whereas in the VR-ND group, 1 participant (S3) was showing elastic demand for the first time and another participant (S2) had not yet shown elastic demand at that point.

In terms of the level of consumption between each group, a repeated-measures ANOVA did not find any statistically significant differences. Price by price comparisons at UP 5 showed the level of consumption was lower for 2 of the 3 participants in the FR#2-ND group(S14 and S15), but this difference was not statistically significant. Consumption levels at UPs 7 and 10, however, were lower in all cases for the FR#2-ND group, and these differences were statistically significant according to an ANOVA at both UP 7, $F(1, 4) = 7.72$, $p = .0499$ and at UP 10, $F(1, 4) = 12.95$, $p = .0228$. Relating to the consumption levels, the magnitudes of the elasticity coefficients between UP 5 and 7, and UP 7 and 10 were larger in every case for the participants in the FR#2-ND group.

VR-D and FR#2-D

The demand curves for these participants are shown in the lower graphs of Figures 22 (VR-D) and 24 (FR#2-D), and the elasticity coefficients for these participants are shown in Table 5. Differences between these 2 groups were found mainly in terms of the point of elasticity and consumption levels, although these comparisons are possibly confounded by sequence. In the FR#2-D group, the demand for 2 out of 3 participants (S16 and S17) became elastic between UP 3 and 5 whereas none of the participants in the VR-D group showed elasticity between these prices. Between UP 5 and 7, 1 participant (S18) in the FR#2-D group showed elastic demand for the first time, the demand for another participant (S16) remained elastic, and the third participant (S17) reverted to inelasticity; demand for 1 participant (S4) in the VR-D group became elastic for the first time between UP 5 and 7. All 3 participants in both groups showed elastic demand between UP 7 and 10; however, it was the first time the demand for 2 of the VR-D participants (S5 and S6) had become elastic.

Overall consumption levels were lower for the FR#2-D participants than for the VR-D participants, and these differences were statistically significant according to a repeated-measures ANOVA, $F(1, 4) = 26.93$, $p = .0066$. Statistically significant differences by price were also found at UP 3, $F(1, 4) = 22.76$, $p = .0088$; UP 5, $F(1, 4) = 12.09$, $p = .0254$; and at UP 7, $F(1, 4) = 9.24$, $p = .0384$. At UP 10, the levels of consumption were mixed between the 2 groups and no statistically significant differences were found. These differences in consumption related to the findings that the demand for the FR#2 group became elastic earlier.

Comparisons of the elasticity coefficients between the 2 groups showed mixed results. One participant in the VR-D group (S4) had a larger elasticity coefficient between UP 5 and 7 than both of the FR#2-D participants (S16 and S17) who showed elastic demand between these prices. Between UP 7 and 10, the magnitudes are mixed between the groups, but this VR group had the participant (S6) with the highest elasticity coefficient.

UP Replications

Consumption levels were examined to determine whether they changed during first and subsequent exposures to the same unit prices. Specifically, comparisons between VR and FR groups involved looking at whether the second or third exposures to the unit prices produced the same, higher, or lower consumption levels. In both of the FR groups, more than half of the consumption levels during second exposures were lower than during the first exposures to the same unit prices, whereas less than half were lower for the VR groups. Specifically, 75% of the replications were lower for the FR group and 69% were lower for the FR#2 group. For the VR groups, only 49% of the replications yielded lower consumption levels than the first exposures.

VR Price Structures

An important issue regarding the use of VR price structures concerns the fact that the schedule value is averaged from a range of numbers. In order for the schedule to average out to the programmed value using a rectangular distribution, all of the numbers within the range would have to be contacted once. Because the participants could terminate the session at any point, it is possible that they could end the session while in the middle of a range and alter the

programmed VR value. Any alteration of the VR value in this experimental situation would in turn alter the price for that participant, creating a difference between the programmed unit price and the obtained unit price.

In order to check for this possibility, the work output for each of the VR participants was divided by consumption to determine the obtained unit price. For UPs 1, 3, 5, and 7, no differences were found between programmed and obtained unit price for any of the VR participants. At UP 10, only1 participant (S6) had a slightly lower obtained unit price (9.3). There were more differences between these values at UP 15, where the obtained unit price was lower for S1 (14.31), lower for S4 (13.68), and higher for S5 (17.6).

CHAPTER 4

DISCUSSION

The general findings from this study were consistent with the law of demand (Bickel et al., 1992) which states that as the price for a particular commodity increases consumption for that commodity will decrease, and that response or work output should be a bitonic function of unit price increases. All of the participants showed a decrease in the consumption of money as a function of an increase in the unit price for money, and unless there was evidence that the sessions had been constrained by the participants, the work outputs were all bitonic functions of increases in unit price. As mentioned previously, 3 participants (S7, S17 and S18) showed relatively flat work output functions, likely due to self-imposed time constraints. This should be taken into consideration when analyzing the demand curves for these participants due to the potential for artificial decreases in consumption. However, discounting the demand curves for these participants did not seem warranted because their work output functions were not completely flat and session durations showed some small fluctuations.

The findings from the present study are also consistent with the findings from previous behavioral economic studies using drug and non-drug reinforcers with both humans and nonhumans. These findings are similar to those shown by DeGrandpre et al. (1994), and Viken (1999), both of which found decreases in the consumption of money as unit price increased. Aside from Viken (1999), when humans have been involved in behavioral economic

investigations, the experimental preparations have involved the use of Lindsley plungers as the response mechanism. The experimental preparation in the present study differed significantly from the most common economic preparations in that the experimental response consisted of solving multiplication problems (as in Viken, 1999). The fact that the same general results were obtained with a preparation different from most studies supports the generality of these effects.

Another finding that was consistent across all of the participants was an increase in the rates of responding across sessions. Due to the nature of the response and the fact that the same problems were used throughout the entire study, it seems as though the participants were able improve in their math problem-solving abilities as the experiment progressed, resulting in an increase in the number of problems solved per minute. Thus, as the participants completed more sessions, the unit price may have been functionally reduced in terms of effort. That is, work effort was reduced as solving the math problems became easier. Participants could solve more problems in the same amount of time, or the same number of problems in less time. The programmed effort, however, remained the same throughout the entire experiment in that the math problems used did not change.

This possible decrease in effort did not seem to have a strong effect on consumption. When the participants encountered the same unit prices during the replications later on the experiment, the average numbers of problems they could solve had increased. Given the possible decrease in effort, it may be reasonable to suggest that consumption on the majority of the replications would be the same or higher than the first exposures. Consumption during the replications was indeed higher in some cases, but many replications showed lower consumption

levels than the first exposure. This makes it appear that the effort reduction obtained in this study was not sufficient to affect price or consumption. It may have been useful to replicate the timed multiplication problems from the pre-screening session and compare the results. Future studies using a similar response, or other responses where the participants' performances can improve, should systematically try to investigate potential relationships between the level of improvement and consumption or work output.

Unit price descriptions produced differential effects based on whether the price was composed of an FR or VR response requirement. Unit price descriptions had a strong effect on consumption when the unit price involved a VR response requirement, but not when the unit price was composed of an FR response requirement. Specifically, the unit price descriptions led to more elastic demand in the VR group (i.e., VR-D) but had very little or no effect on the demand for either FR group.

During post-session interviews, the participants in the FR-ND group reported being able to count the response requirements in each session and compare between sessions. This may account for the lack of differences observed in both FR groups between the description and no-description conditions in that after the first reinforcer delivery in the no-description condition, the 2 groups essentially had the same information about the response requirement. The use of VR schedules made the response requirement in effect for any particular session less discriminable and none of these participants reported being able to count the response requirements. Providing unit price descriptions to some of the participants in the VR group, however, dramatically reduced consumption levels compared to the levels of those participants

who did not receive the descriptions. Because the response requirements varied within a certain range at each price, it seems likely that the VR-ND participants would also have difficulty discriminating response requirements between prices. Both post-experiment interviews and the data for these participants, however, suggests that discriminating between prices did not pose a significant problem. The participants could not state what the particular prices were in each session, yet they reported being able to generally tell that the price increased or decreased across sessions. Furthermore, the demand curves for the participants in the VR-ND group showed some decreases in consumption across increasing prices. Had participants been completely unable to discriminate between prices, the demand curves might have fluctuated between prices or been flat across the entire range of prices.

One way to interpret these results is in terms of the discriminability within each price and between prices. Within-price discriminability refers to being able to determine the number of responses required to earn each unit of the reinforcer at each price. Between-price discriminability refers to the ability to determine the difference in the number of responses required at different prices in different sessions. The participants in both FR groups, regardless of whether they received descriptions, may have had both high within-price and between-price discriminability. The VR-ND participants may have had low within-price discriminability and moderate to high between-price discriminability. Giving the unit price descriptions to the VR-D participants may have increased within and between-price discriminability, making the demand for these participants more similar to the demand for the participants in the FR groups; both

groups showed more elastic demand and lower levels of consumption. This analysis suggests that unit price descriptions may have their effect through their influence on price discriminability.

For the participants in the FR groups, it did not seem likely that discriminating between prices would present much of an issue as a result of having constant within-price response requirements. For the participants in the VR group, discriminating between prices posed a concern in that the response requirements varied within a given range at each price and any overlap in the ranges between prices could hinder discriminability. The range of values used at each price in the present study were designed so there would be minimal overlap in the response requirements used at each price. Only three values (i.e., response requirements) overlapped in the ranges between UP 5 and 7, and UP 7 and 10, one value overlapped between UP 10 and 15, and no overlap occurred at the lower prices. Selecting the ranges in this manner may have increased between-price discriminability somewhat for the VR-ND participants.

Unit price descriptions may also act as a more direct economic influence on the behavior of the participants. Some of the participants who received unit price descriptions from both the VR and FR groups reported equating the price information to typical wage rates. Upon receiving the descriptions they reported calculating whether what they could earn that session would equal minimum wage rates and used that information to determine how many problems they would solve. This possibility suggests that unit price descriptions may affect demand by supplying wage rate information that allows participants to compare the economics of the experimental session to other work settings.

In terms of the variable or fixed unit price structures, slight differences were suggested in that the participants in the FR groups tended to show elastic demand between lower prices than did the participants in the VR groups. This difference was more pronounced between the no-description groups. These findings are consistent with the notion that price discriminability may be an important variable in affecting elasticity. The VR-ND group had little to no within-price discriminability, whereas both FR groups and the VR-D group had high within-price discriminability. It seems reasonable, therefore, that the VR-ND and FR-ND groups showed larger differences than did the VR-D and FR-D groups did, in that the 2 no-description groups differed in terms of both unit price structure and price discriminability. However, the fact that both VR-D and FR-D groups also had apparent differences despite high price discriminability suggests that something about a variable price structure other than discriminability can affect consumption.

Considering previous research conducted with FR and VR schedules, it is not surprising that unit prices constructed with VR schedules would produce different effects from those constructed with FR schedules. Past research has consistently found that both higher rates of responding and more persistent responding occur under VR schedules of reinforcement than under FR schedules (Catania, 1998). Consistent with these findings suggesting that VR schedules have stronger motivational properties, in terms of higher rates of responding and more resistance to extinction (Catania, 1998), demand under the VR prices was more inelastic than under the FR prices. In economic preparations, therefore, the motivational properties of VR schedules may be seen in their effect on demand more than on response rate. Although no

overall difference in rate of responding between the VR and FR groups was observed, the highest rates for particular sessions were produced by VR participants. Furthermore, the VR price structures generally produced higher levels of consumption on second exposures to the same unit prices than did the FR price structures. Therefore, it appears that some of the same mechanisms through which VR schedules have produced differences in other lines of research are also present when VR schedules are used to construct unit prices. It may simply be the case that a variable response requirement reduces sensitivity to price increases relative to a fixed response requirement. The fact that the VR-ND group showed the most inelastic demand of any group suggests that a variable price structure and low price discriminability acting in combination can have a strong effect in reducing elasticity.

Regarding unit price sequence, a slight difference between the FR groups exposed to different sequences was apparent. The demand for the participants in both FR#2 groups became elastic earlier than the demand for both FR groups regardless of unit price descriptions. These data suggest that the sequence of exposure to unit prices may affect the elasticity of demand. That these effects did not interact with the unit price descriptions is consistent with the findings that descriptions did not differentially affect consumption with FR price structures. The sequences between these groups varied at several points throughout the experiment, and had a range of changes between prices in different directions (e.g., from UP 7 to 10 or from UP 10 to 5). The fact that this manipulation was not planned prevented systematic comparisons between the two sequences. Exposures to certain prices occurred during different sessions between these groups, which confounded point to point comparisons at certain prices with exposure to

previous prices and the direction and magnitude of the change. Taking this into consideration, the fact that some differences did appear between these two sequences indicates a need for this issue to be investigated further in a more systematic manner.

Another possible variable that may have influenced the differences between the FR and FR#2 groups concerns the semester during which the participants took part in the experiment. The FR#2 group participated during the spring semester, whereas the FR group participated during the summer semester. It may be the case that the more inelastic demand shown in the FR group was a result of several factors associated with participating during the summer, such as having a more lenient schedule and a greater need for money. Some participants' behavior and post-session interviews gave some indication that this may have been occurring. For example, participant S11 in the FR-D group was the only participant to take multiple breaks throughout the experiment, and even took repeated breaks during the same session. The majority of these breaks occurred during exposures to UP 7, where this participant took multiple breaks averaging approximately 10-15 min, leading to total session durations (including breaks) ranging from approximately 1 ½ to 2 ½ hrs. This participant also reported a greater need for money due to her financial situation during the summer. Another participant, S8, from the FR-ND group, reported having made a large purchase before beginning the experiment and was using the money earned from this experiment to help with the payments. It is interesting to note that both of these participants showed the most inelastic demand of any participant in either FR group.

The possibility of some kind of a "summer effect" relates to the fact that an open economy exists with respect to money. In other words, the money earned from this experiment did not serve as the only source of income for any of these participants. It may be the case that more sources of income are available during a regular school semester as opposed to during summer, which would in turn serve to close the economy to some degree in summer and lead to higher demand. In general, there is only a slight indication that some effect may have occurred as a result of conducting the experiments during the summer. A more systematic investigation of this issue would be required to ascertain whether or not it is a relevant variable.

Although comparisons between the VR group and the FR#2 group are weak due to sequence confounds, the differences between these 2 groups are interesting to discuss in terms of the previous findings. The participants in both FR#2 groups showed more elastic demand than the participants in the VR groups, but this effect was much more apparent between the no-description groups. These differences are consistent with the previous findings in that the VR-ND group showed the most inelastic demand, both VR groups overall showed more inelastic demand than the FR groups, and the FR#2 groups showed the most elastic demand. Therefore, it is not surprising that the VR-ND group differed to such a large degree from the FR#2-ND group. It is also not surprising that these differences were not as large between the VR-D and FR#2-D groups. The VR-D group showed more elastic demand than the VR-ND group and was thus more similar to the FR#2-D group.

In general, findings from this study suggest that FR and VR price structures have different economic effects. This effect has not been demonstrated previously. Both type of

price structures produce effects consistent with the law of demand, but elasticity appears to be affected differentially. In terms of real world economic choices, variable price structures seem to be very well represented in that very few commodities maintain a consistent price for an extended period of time. Furthermore, the prices for these commodities can vary in terms of dollar amounts as well as effort. Investigating VR price structures in an experimental setting may approximate real world situations more closely. This does not detract from the utility of using FR price structures; their reliability and generality has been adequately demonstrated. More research using VR price structures is clearly needed. For example, it would be useful to investigate VR price structures using different reinforcers and even under different economic constraints (i.e., closed economies). Furthermore, research should be conducted on the types of distributions used to generate VR schedules to determine if different distributions lead to different economic effects.

The results of this study also indicate that providing or not providing contingency descriptions is an important issue for many procedures involving human participants. These data show specifically that price descriptions are especially relevant in an economic framework when using VR price structures. Previous studies that have given unit price descriptions have also used FR price structures, so the unit price descriptions probably had very little effect.

The type of description used in the present experiment was previously discussed in relation to contingency descriptions used in traditional reinforcement schedule research. The equivalence of these types of descriptions across the different lines of research is questionable, although both offer similar kinds of information in each case. Reinforcement schedule research

has shown that contingency descriptions do not have a differential effect on responding on RR and RI schedules unless they are paired with some type of performance description (see Catania et al., 1989; Matthews et al., 1985). These studies measured changes in sensitivity to particular schedules, which is different from the type of information gathered in behavioral economic investigations.

Taking the limitations of this comparison into consideration, the present study showed that economic contingency descriptions had a large effect on responding with VR price structures, unlike the weak effects of contingency descriptions in the previously mentioned schedule research. This difference is puzzling, especially in light of the fact that the schedule research involved RR schedules which are similar to the VR schedules used in the present experiment. This suggests that economic preparations using VR price structures may be especially sensitive to some kinds of instructional effects. Therefore, these types of economic preparations may prove to be useful for the study of instructional variables.

One limitation of the present study, concerns the small number of participants within each experimental group. Future research should involve larger groups in order to determine the reliability of the effects. Another alternative may be to investigate some of these issues using a within-subject experimental design. This type of design would be problematic for investigating unit price descriptions in that once descriptions are given, they cannot be removed. However, a within-subject design would be appropriate to study the effects of fixed or variable price structures and sequence effects.

The findings from the present study suggest several issues with significant implications for future research conducted within behavioral economics as well as in general human operant research. However, because this is one of the first studies to investigate some of these issues, replications are needed to test the generality of the findings.

APPENDIX A

SCREENING QUESTIONS, MULTIPLICATION TESTS, DEBRIEFING QUESTIONS, AND INFORMED CONSENT FORM

Screening Questions for Joey's research

Name of Participant: _____

Date of Birth: _____

Name of Experimenter: _____

- **Do you have the ability to look at a computer screen for an extended period of time?**

  Yes_____ **No_____**

- **Can you read small text on a computer screen?**

  Yes_____ **No_____**

- **Do you have any problems using your hands to work a computer keyboard for an extended period of time**

  Yes_____ **No_____**

- **Do you have any inhibitions to work in a room by yourself?**

  Yes_____ **No_____**

- **Do you have an extended understanding of basic research in behavior analysis**

  Yes_____ **No_____**

- **Do you have any commitments following the times that you have signed up for that may conflict with your participation?**

  Yes_____ **No_____**

Participant's signature / Date **Experimenter's signature / Date**

_____ _____

Screening Math Problems

NAME: _____

1x1=	**2x1=**	**3x1=**	**4x1=**	**5x1=**
1x2=	**2x2=**	**3x2=**	**4x2=**	**5x2=**
1x3=	**2x3=**	**3x3=**	**4x3=**	**5x3=**
1x4=	**2x4=**	**3x4=**	**4x4=**	**5x4=**
1x5=	**2x5=**	**3x5=**	**4x5=**	**5x5=**
1x6=	**2x6=**	**3x6=**	**4x6=**	**5x6=**
1x7=	**2x7=**	**3x7=**	**4x7=**	**5x7=**
1x8=	**2x8=**	**3x8=**	**4x8=**	**5x8=**
1x9=	**2x9=**	**3x9=**	**4x9=**	**5x9=**
1x10=	**2x10=**	**3x10=**	**4x10=**	**5x10=**

6x1=	**7x1=**	**8x1=**	**9x1=**	**10x1=**
6x2=	**7x2=**	**8x2=**	**9x2=**	**10x2=**
6x3=	**7x3=**	**8x3=**	**9x3=**	**10x3=**
6x4=	**7x4=**	**8x4=**	**9x4=**	**10x4=**
6x5=	**7x5=**	**8x5=**	**9x5=**	**10x5=**
6x6=	**7x6=**	**8x6=**	**9x6=**	**10x6=**
6x7=	**7x7=**	**8x7=**	**9x7=**	**10x7=**
6x8=	**7x8=**	**8x8=**	**9x8=**	**10x8=**
6x9=	**7x9=**	**8x9=**	**9x9=**	**10x9=**
6x10=	**7x10=**	**8x10=**	**9x10=**	**10x10=**

Screening Math Problems

NAME: _____

5 x 6=	**10 x 8=**	**6 x 7=**
7 x 8=	**7 x 4=**	**7 x 10=**
1 x 3=	**5 x 2=**	**8 x 9=**
3 x 6=	**1 x 8=**	**2 x 2=**
8 x 2=	**3 x 9=**	**8 x 5=**
10 x 5=	**9 x 7=**	**7 x 7=**
6 x 7=	**8 x 3=**	**10 x 3=**
9 x 5=	**6 x 3=**	**1 x 6=**
2 x 2=	**4 x 4=**	**3 x 7=**
4 x 9=	**2 x 10=**	**5 x 1=**
2 x 8=	**9 x 1=**	**4 x 2=**
5 x 7=	**3 x 4=**	**7 x 3=**
2 x 4=	**10 x 2=**	**6 x 6=**
8 x 7=	**8 x 1=**	**1 x 4=**
9 x 10=	**4 x 8=**	**10 x 6=**
10 x 10=	**1 x 2=**	**10 x 6=**
2 x 9=	**8 x 4=**	**4 x 2=**
5 x 5=	**7 x 5=**	**7 x 3=**
8 x 9=	**9 x 8=**	**6 x 6=**
4 x 6=	**6 x 10=**	**1 x 4=**
3 x 3=	**2 x 1=**	**3 x 10=**
4 x 7=	**1 x 5=**	**6 x 8=**
7 x 10=	**5 x 3=**	**5 x 6=**
8 x 6=	**3 x 10=**	**4 x 10=**
9 x 9=	**6 x 5=**	**6 x 6=**
5 x 8=	**10 x 9=**	**1 x 1=**
7 x 6=	**8 x 5=**	**6 x 8=**
3 x 1=	**6 x 1=**	**7 x 9=**
6 x 4=	**4 x 3=**	**3 x 8=**
8 x 8=	**1 x 5=**	**5 x 9=**
10 x 4=	**10 x 7=**	**9 x 2=**
3 x 2=	**6 x 9=**	**10 x 8=**
4 x 5=	**4 x 1=**	**2 x 6=**
9 x 2=	**1 x 10=**	**4 x 7=**
2 x 6=	**3 x 5=**	**7 x 1=**

Debriefing Questions for No Description Groups

1. What do you think the purpose of this experiment is?

2. What made you decide how much money you would earn?

3. How important was it for you to earn the money

    - What was the main motivator for you to complete the experiment?

4. Did you at any point want to stop coming to the experiment?

5. Did you ever run out of time or get in a rush for other things while you were participating in the experiment?

    - What did you usually do after you finished the sessions?

6. Were the number of math problems you needed to solve to get the five cents always the same?

Debriefing Questions for Description Groups

1. What do you think the purpose of this experiment is?

2. What made you decide how much money you would earn?

3. How important was it for you to earn the money

    - What was the main motivator for you to complete the experiment?

4. Did you at any point want to stop coming to the experiment?

5. Did you ever run out of time or get in a rush for other things while you were participating in the experiment?

    - What did you usually do after you finished the sessions?

6. When I told you at the beginning of each session how many problems you would have to solve to earn the money, how did that influence how you would respond in the session?

Informed Consent Form

My name is Jorge Reyes, and I am a graduate student at the University of North Texas. I am requesting your consent to participate in a research study. The results from this study will be presented at a conference.

Please read the following consent form carefully before signing.

I understand that taking part in this experiment will last for a minimum of 15 sessions (approximately 2-3 weeks.) Only one session will be conducted each day of participation. I will earn varying amounts of money during sessions for solving math problems on a computer and I will obtain a $25 bonus upon completion of the 15 sessions. After the experiment I will be debriefed and be able to ask questions regarding the experiment. Benefits of participation include the potential for earning money during every session and a $25 bonus for completing the experiment. There are no foreseen risks as a result of participating in this study.

I have been informed that any information obtained in this experiment will be coded by use of arbitrary numbers and the data will be kept locked up without access to anyone but the experimenters. Under these conditions, I agree that any information obtained in the study may be subject for publications and public presentations. Participation in this study is voluntary and I have the right to view data at the conclusion of the experiment and determine to discontinue my participation at any time without penalty, prejudice or loss of benefits.

If I have any questions or problems that arise in connection with the participation in this study, I will contact Jorge Reyes at (940) 565-3538 (Department of Behavior Analysis) or Dr. Cloyd Hyten at (940) 565-4071 (Department of Behavior Analysis).

Name of participant (please print) _____

_____ _____

Date Signature of Participant

_____ _____

Date Signature of Principal Investigator

This project has been reviewed and approved by the
UNT Committee for the Protection of Human Subjects (940-565-3940)

APPENDIX B

TABLES

Table 1. Unit price sequence (including replications) for all participants

Group	UP - Sequence	Sessions
VR-Group		
S1	1, 3, 7, 5, 10, 1, 3, 7, 5, 10, 7, 15	12
S2	1, 3, 7, 5, 10, 1, 3, 7, 5, 10, 15	11
S3	1, 3, 7, 5, 10, 1, 3, 7, 5, 10, 15	11
S4	1, 3, 7, 5, 10, 1, 3, 7, 5, 10, 15	11
S5	1, 3, 7, 5, 10, 1, 3, 7, 5, 10, 7, 15	12
S6	1, 3, 7, 5, 10	5
FR-Group		
S7	1, 3, 7, 5, 10, 1, 3, 7, 5, 10	10
S8	1, 3, 7, 5, 10, 1, 3, 7, 5, 10	10
S9	1, 3, 7, 5, 10, 1, 3, 7, 5, 10	10
S10	1, 3, 7, 5, 10, 1, 3, 7	8
S11	1, 3, 7, 5, 10, 1, 3, 7, 5, 10, 7	11
S12	1, 3, 7, 5, 10, 1, 3, 7, 5, 10	10
FR #2-Group		
S13	1, 3, 7, 5, 1, 10, 5, 3, 7, 10, 7, 5	12
S14	1, 3, 7, 5, 1, 10, 5, 3, 7, 10, 7	11
S15	1, 3, 7, 5, 1, 10, 5	7
S16	1, 3, 7, 5, 1, 10, 5, 3, 7, 10	10
S17	1, 3, 7, 5, 1, 10, 5, 3, 7, 10	10
S18	1, 3, 7, 5, 1, 10, 5, 3, 7, 10	10

Table 2. Rate of responding (problems per minute) during the first and last sessions for all participants. Change in rate shown in the Difference column.

		Rate		
		First Session	Last Session	Difference
VR - ND	S1	23.86	44.26	20.40
	S2	33.90	60.91	27.01
	S3	40.82	55.58	14.76
VR - D	S4	45.28	60.53	15.25
	S5	36.41	56.05	19.64
	S6	40.46	29.66	-10.80
FR - ND	S7	33.84	46.05	12.21
	S8	36.19	55.87	19.68
	S9	47.51	55.98	8.47
FR - D	S10	22.71	43.36	20.65
	S11	43.38	51.11	7.73
	S12	27.76	39.79	12.03
FR #2 - ND	S13	20.28	41.49	21.21
	S14	48.08	55.64	7.56
	S15	27.05	30.49	3.44
FR #2 - D	S16	38.46	49.30	10.84
	S17	20.36	40.08	19.72
	S18	24.67	35.28	10.61

Table 3. Total consumption (C) in cents and work output (W) in number of responses at every unit price for all particpants in the VR group. First, second, or third exposure to each price are shown in rows

VR - ND

Unit Price	S1		S2		S3	
	C	W	C	W	C	W
UP 1 (5/5)	600	600	600	600	600	600
	600	600	600	600	600	600
UP 3 (15/5)	600	1797	600	1801	600	1798
	600	1797	600	1803	600	1798
UP 5 (25/5)	505	2532	600	3002	600	3000
	545	2728	600	3002	600	2999
UP 7 (35/5)	420	2931	540	3781	600	4200
	270	1881	430	3025	470	3308
	385	2697				
UP 10 (50/5)	205	2056	375	3750	335	3337
	205	2056	395	3962	345	3440
UP 15 (75/5)	90	1288	160	2415	140	2112

VR - D

Unit Price	S4		S5		S6	
	C	W	C	W	C	W
UP 1 (5/5)	600	600	600	600	600	600
	600	600	600	600		
UP 3 (15/5)	600	1801	600	1798	580	1734
	600	1797	600	1797		
UP 5 (25/5)	560	2798	270	1347	350	1752
	475	2383	505	2530		
UP 7 (35/5)	250	1752	515	3606	270	1888
	100	691	315	2205		
			205	1435		
UP 10 (50/5)	65	649	250	2509	15	140
	85	846	100	1007		
UP 15 (75/5)	25	342	5	88		

Table 4. Total consumption (C) in cents and work output (W) in number of responses at every unit price for all participants in the FR group. First, second, or third exposure to each price are shown in rows.

FR - ND

Unit Price	S7		S8		S9	
	C	W	C	W	C	W
UP 1 (5/5)	600	600	600	600	600	600
	600	600	600	600	600	600
UP 3 (15/5)	370	1110	600	1800	600	1800
	335	1005	600	1800	600	1800
UP 5 (25/5)	250	1250	230	1150	600	3000
	200	1000	595	2976	155	775
UP 7 (35/5)	125	908	600	4200	250	1768
	185	1295	425	2976	115	805
UP 10 (50/5)	100	1000	450	4501	175	1785
	70	700	20	200	110	1100

FR - D

Unit Price	S10		S11		S12	
	C	W	C	W	C	W
UP 1 (5/5)	600	600	600	600	600	600
	600	600	600	600	600	600
UP 3 (15/5)	600	1800	600	1800	600	1800
	600	1800	600	1800	600	1800
UP 5 (25/5)	170	850	600	3000	600	3000
			385	1925	265	1325
UP 7 (35/5)	100	700	600	4200	260	1835
	105	735	600	4200	70	490
			600	4200		
UP 10 (50/5)	35	350	180	1800	80	800
			55	550	15	150

Table 5. Total consumption (C) in cents and work output (W) in number of responses at every unit price for all participants in the FR #2 group. First, second, or third exposure to each price are shown in rows.

FR #2 - ND

Unit Price	S13		S14		S15	
	C	W	C	W	C	W
UP 1 (5/5)	600	600	600	600	600	600
	600	600	600	600	600	600
UP 3 (15/5)	600	1800	600	1800	200	600
	355	1065	600	1800		
UP 5 (25/5)	230	1150	600	3000	15	75
	145	725	600	3000	5	25
	235	1175				
UP 7 (35/5)	285	1995	460	3220	10	70
	135	946	190	1330		
	100	700	410	2870		
UP 10 (50/5)	45	452	130	1300	5	50
	65	650	155	1550		

FR #2 - D

Unit Price	S16		S17		S18	
	C	W	C	W	C	W
UP 1 (5/5)	600	600	600	600	600	600
	600	600	600	600	600	600
UP 3 (15/5)	600	1800	250	750	205	615
	255	765	220	660	355	1076
UP 5 (25/5)	300	1500	110	558	240	1200
	155	775	75	375	215	1084
UP 7 (35/5)	145	1016	105	735	105	763
	40	280	75	525	170	1206
UP 10 (50/5)	70	700	30	300	95	992
	25	250	40	400	85	882

Table 6. Elasticity coefficients for all participants.
Shaded areas indicate elastic demand.

		Unit Price Changes				
		1 - 3	3 - 5	5 - 7	7 - 10	10 - 15
VR - ND	S1	0.00	0.27	1.14	1.54	1.95
	S2	0.00	0.00	0.64	0.65	2.07
	S3	0.00	0.00	0.35	1.26	2.08
VR - D	S4	0.00	0.30	3.00	2.27	2.50
	S5	0.00	0.86	0.35	1.85	4.72
	S6	0.30	0.99	0.78	5.07	
FR - ND	S7	0.51	0.88	1.00	1.65	
	S8	0.00	0.74	-0.66	2.10	
	S9	0.00	0.91	2.09	0.70	
FR - D	S10	0.00	2.23	1.50	2.78	
	S11	0.00	0.39	-0.60	3.81	
	S12	0.00	0.65	2.71	3.13	
FR #2 - ND	S13	0.23	1.61	0.48	2.94	
	S14	0.00	0.00	1.61	2.41	
	S15	1.00	3.62	0.00	1.89	
FR #2 - D	S16	0.34	1.22	2.53	1.82	
	S17	0.87	1.74	0.10	2.49	
	S18	0.73	0.41	1.48	1.18	

APPENDIX C

FIGURES

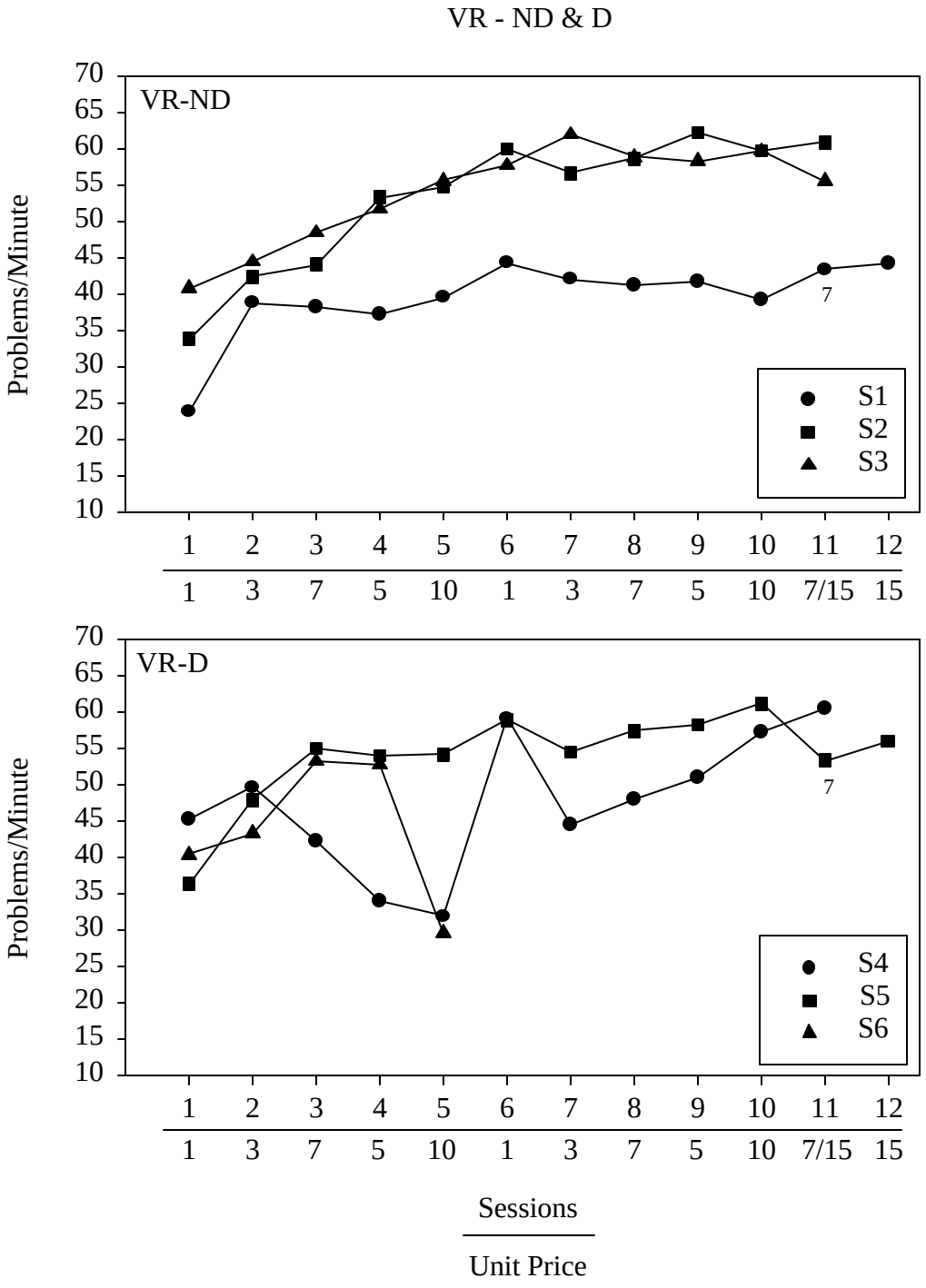

Figure 1. Rate of responding (problems/minute) for each participant in the VR group across sessions. Values above the line indicate the session number, values below the line indicate the price in effect for that particular session.

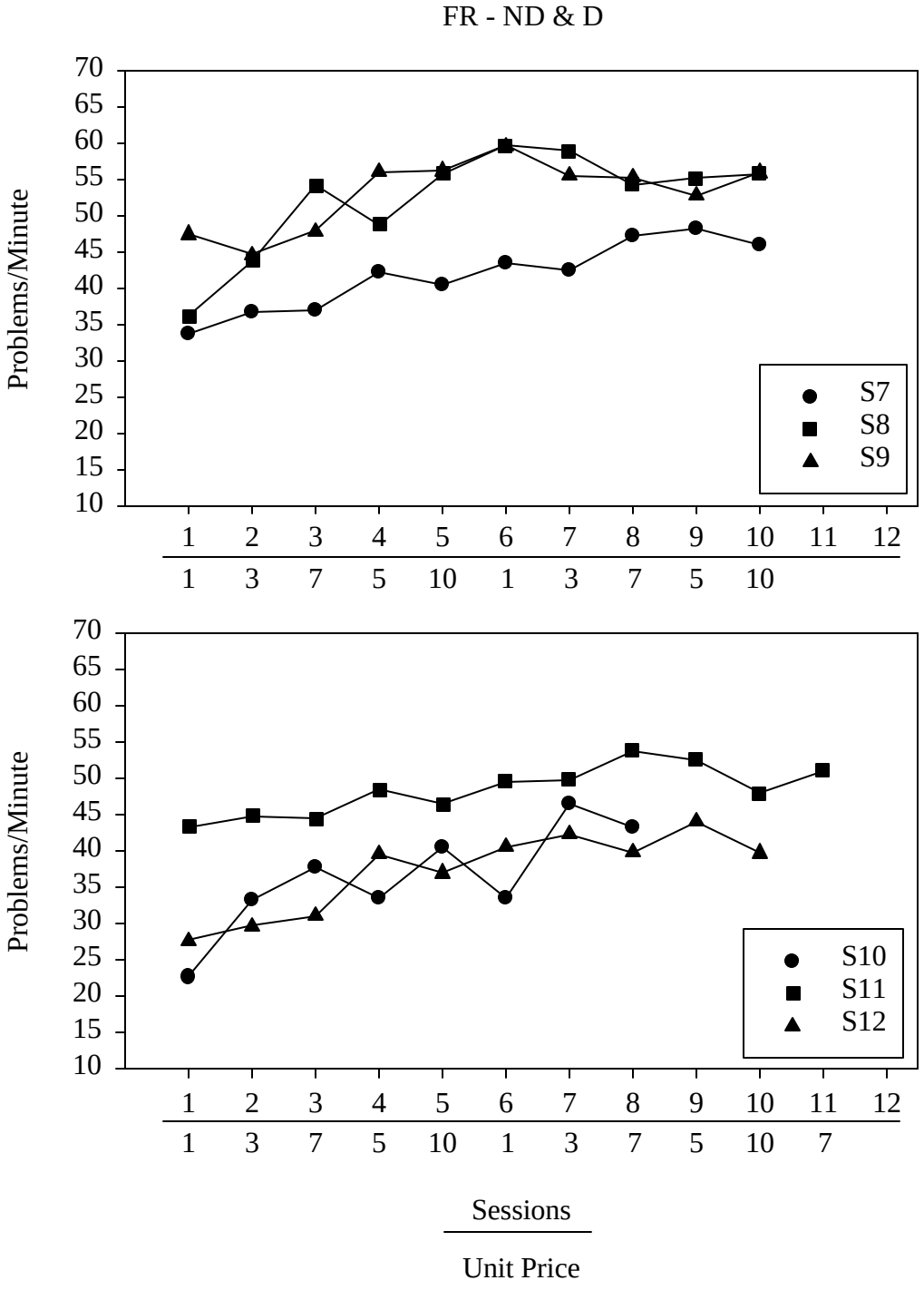

Figure 2. Rate of responding (problems/minute) for each participant in the FR group across sessions. Values above the line indicate the session number, values below the line indicate the price in effect for that particular session.

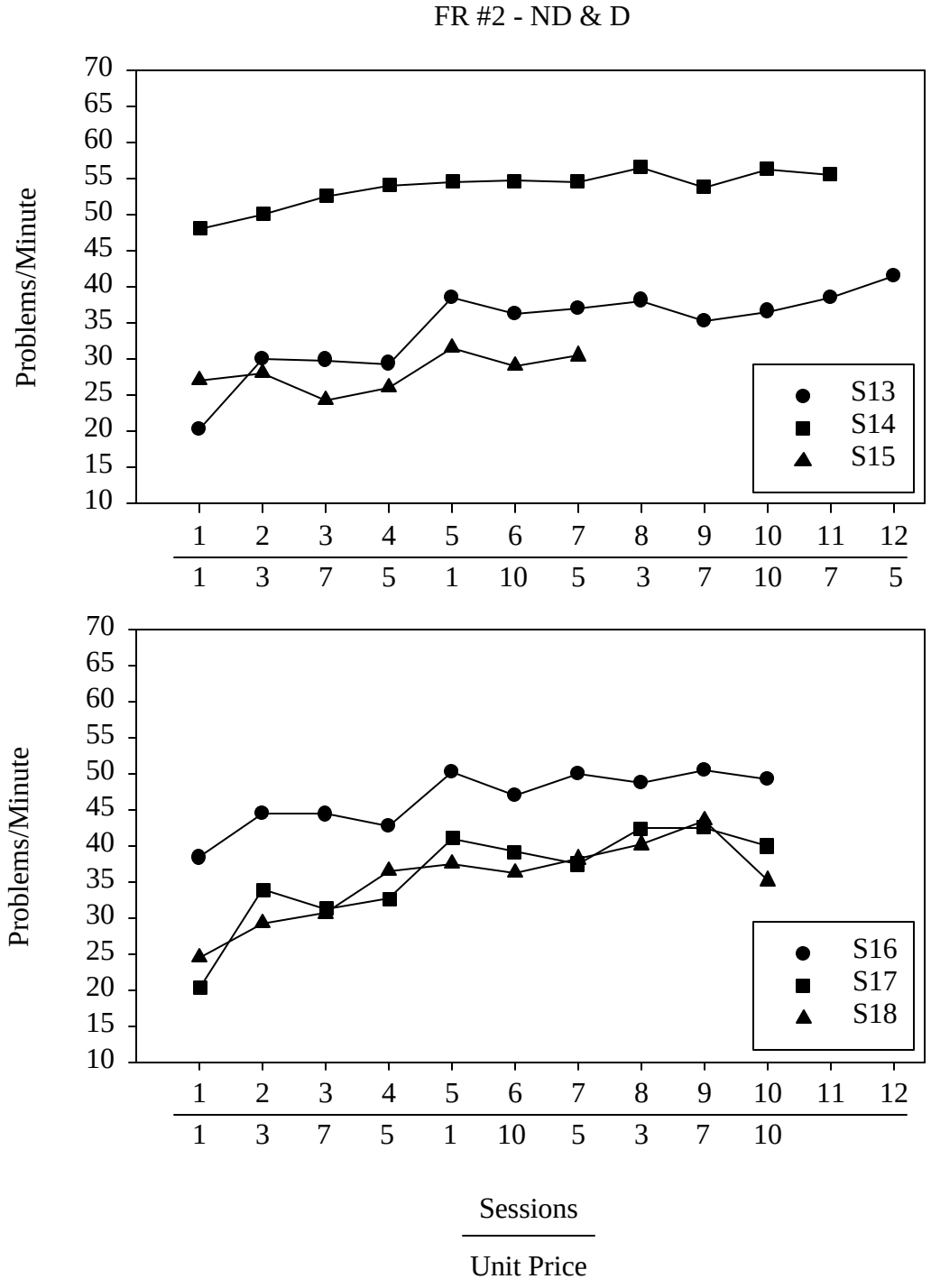

Figure 3. Rate of responding (problems/minute) for each participant in the FR#2 group across sessions. Values above the line indicate the session number, values below the line indicate the price in effect for that particular session.

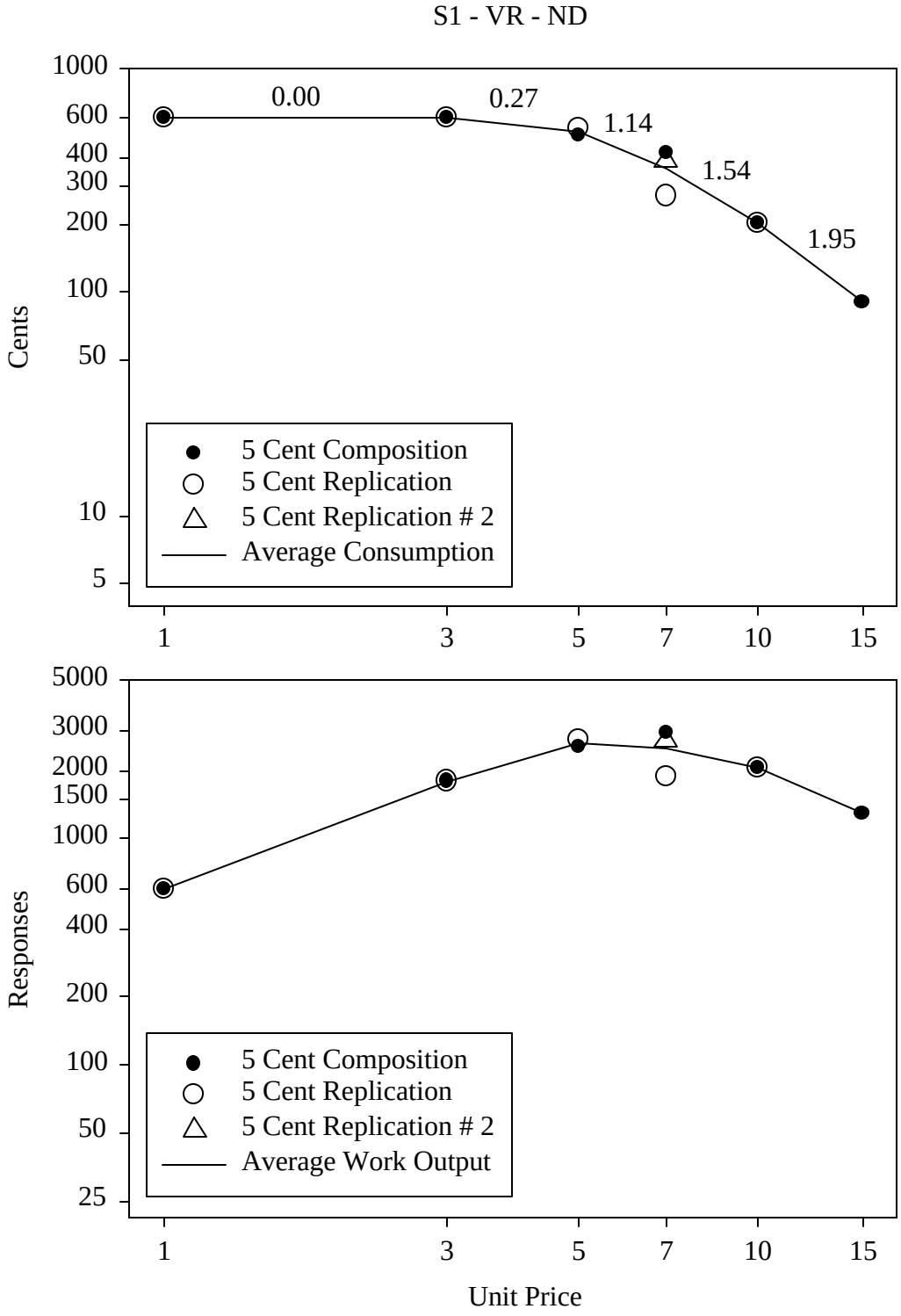

Figure 4. Demand curve (top graph) and work output curve (bottom graph) plotted in log-log units. Lines denote average values of consumption (top graph) and work output (bottom graph). Values on top of the demand curve indicate elasticity coefficients.

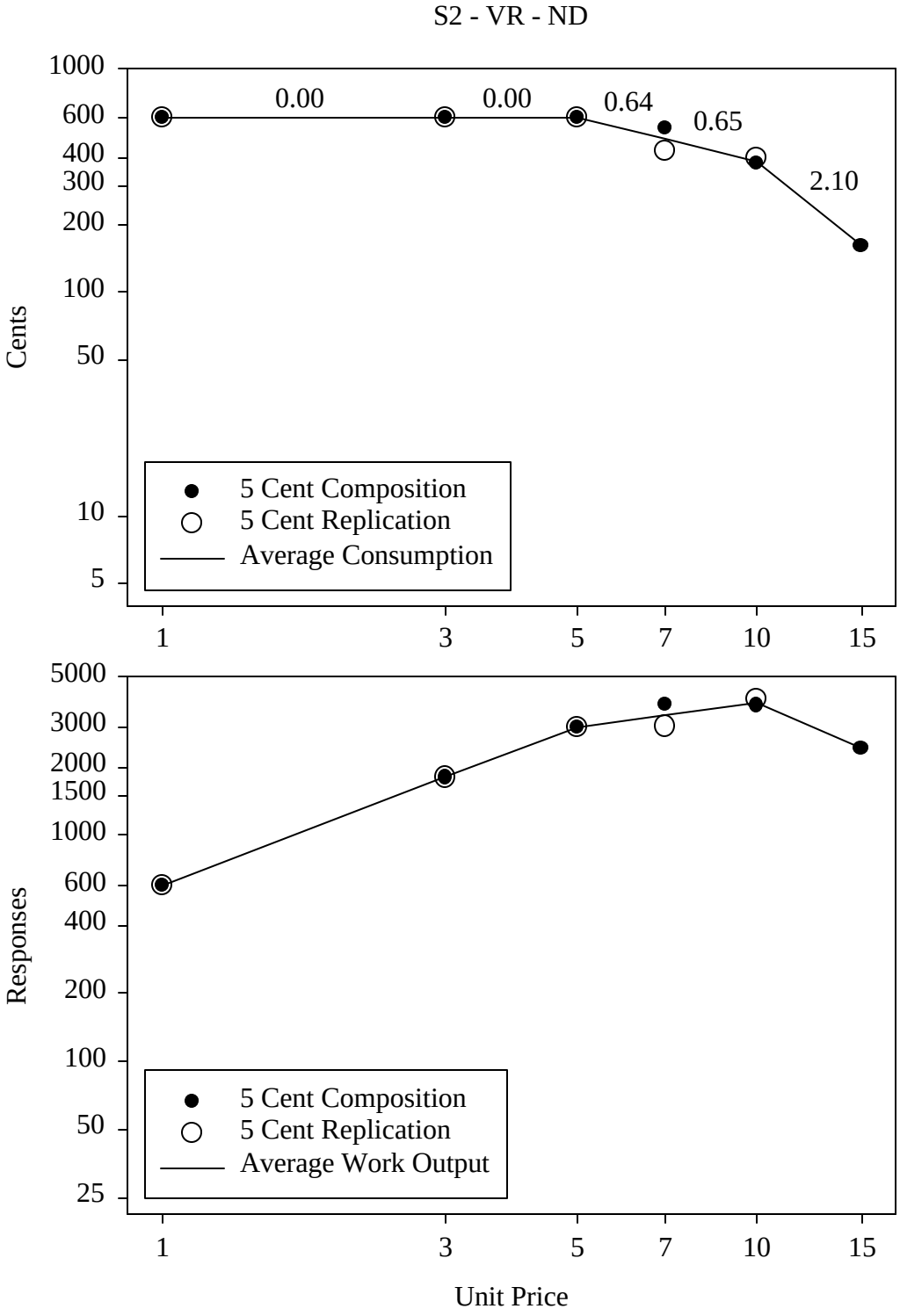

Figure 5. Demand curve (top graph) and work output curve (bottom graph) plotted in log-log units. Lines denote average values of consumption (top graph) and work output (bottom graph). Values on top of the demand curve indicate elasticity coefficients.

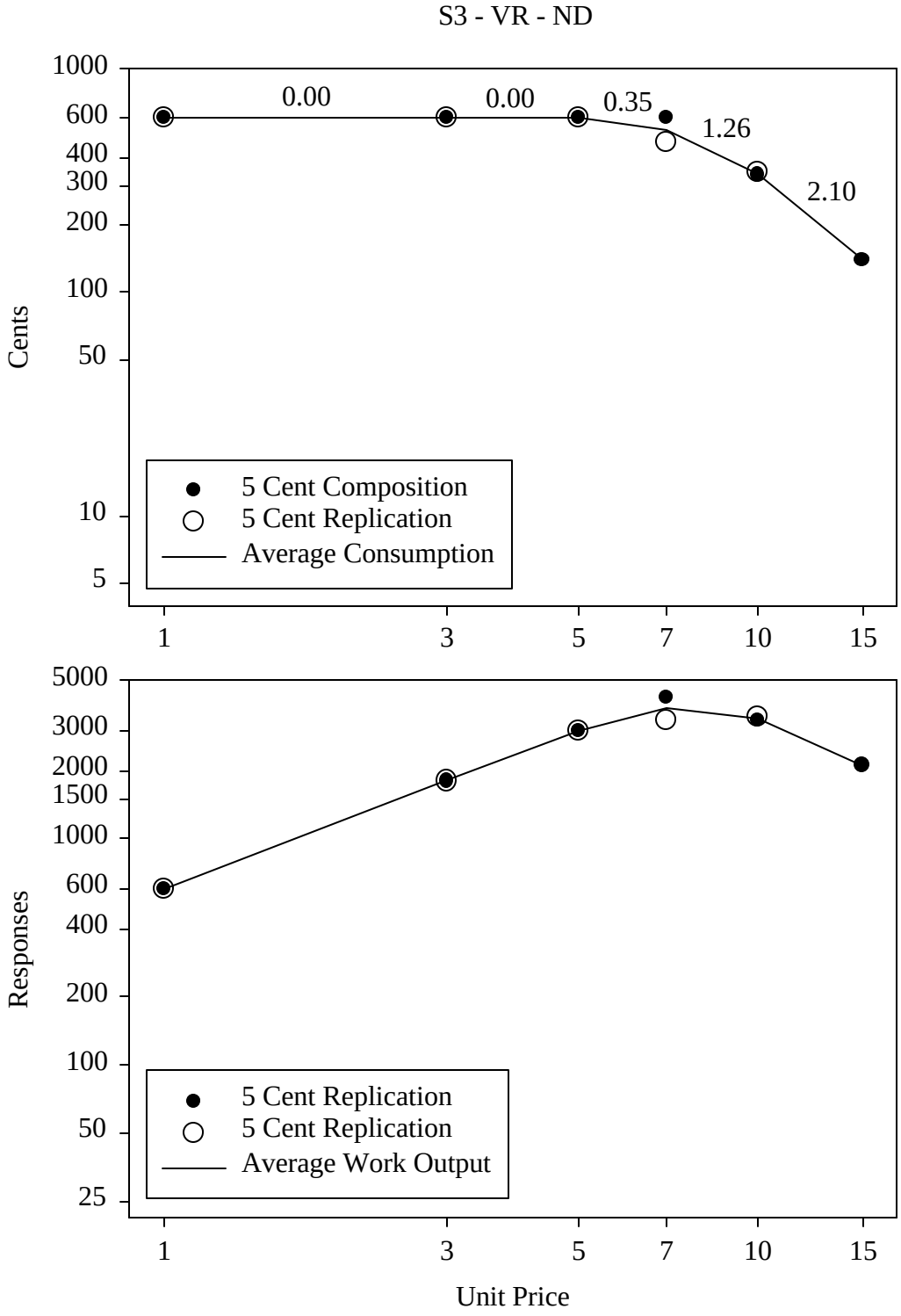

Figure 6. Demand curve (top graph) and work output curve (bottom graph) plotted in log-log units. Lines denote average values of consumption (top graph) and work output (bottom graph). Values on top of the demand curve indicate elasticity coefficients.

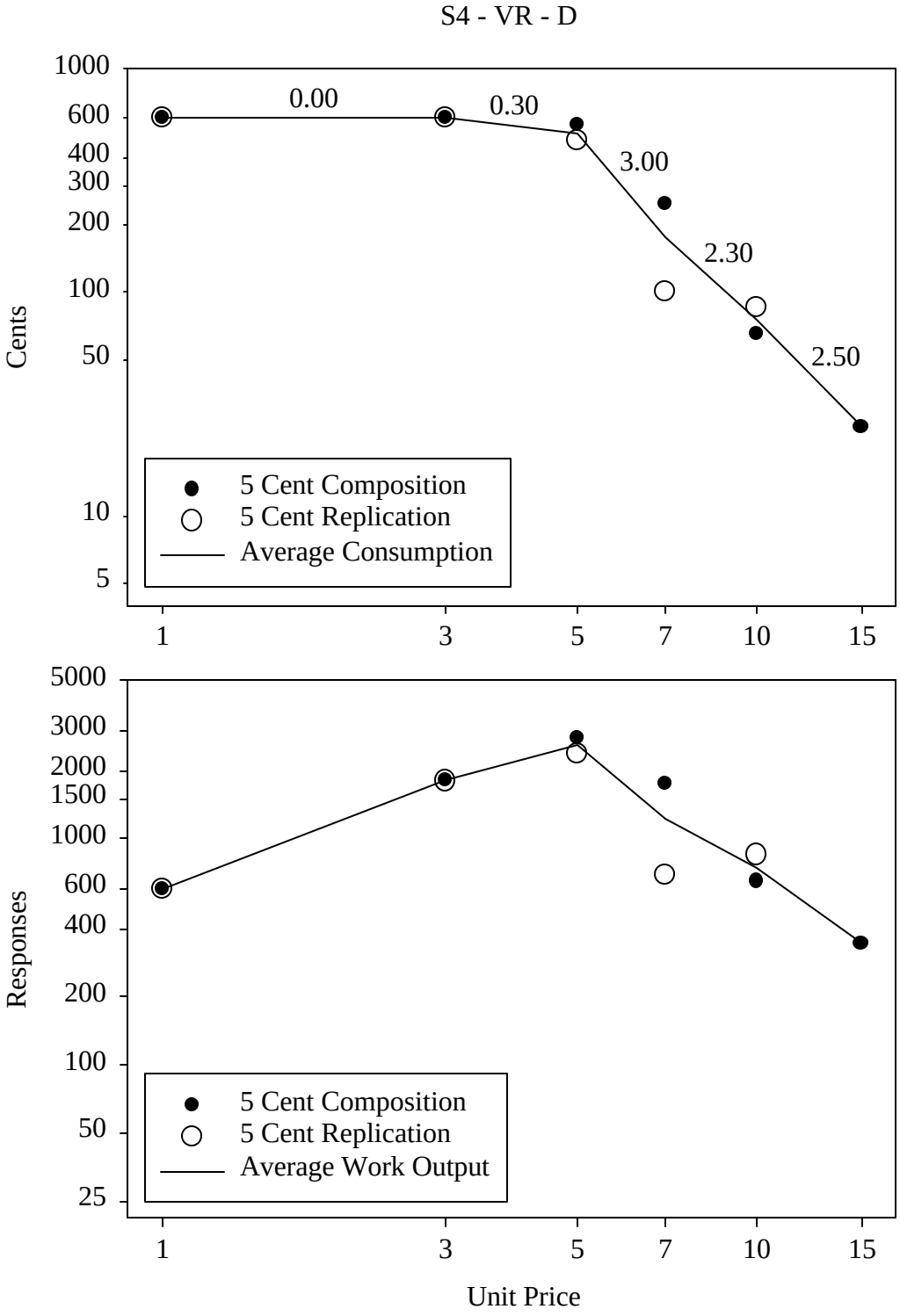

Figure 7. Demand curve (top graph) and work output curve (bottom graph) plotted in log-log units. Lines denote average values of consumption (top graph) and work output (bottom graph). Values on top of the demand curve indicate elasticity coefficients.

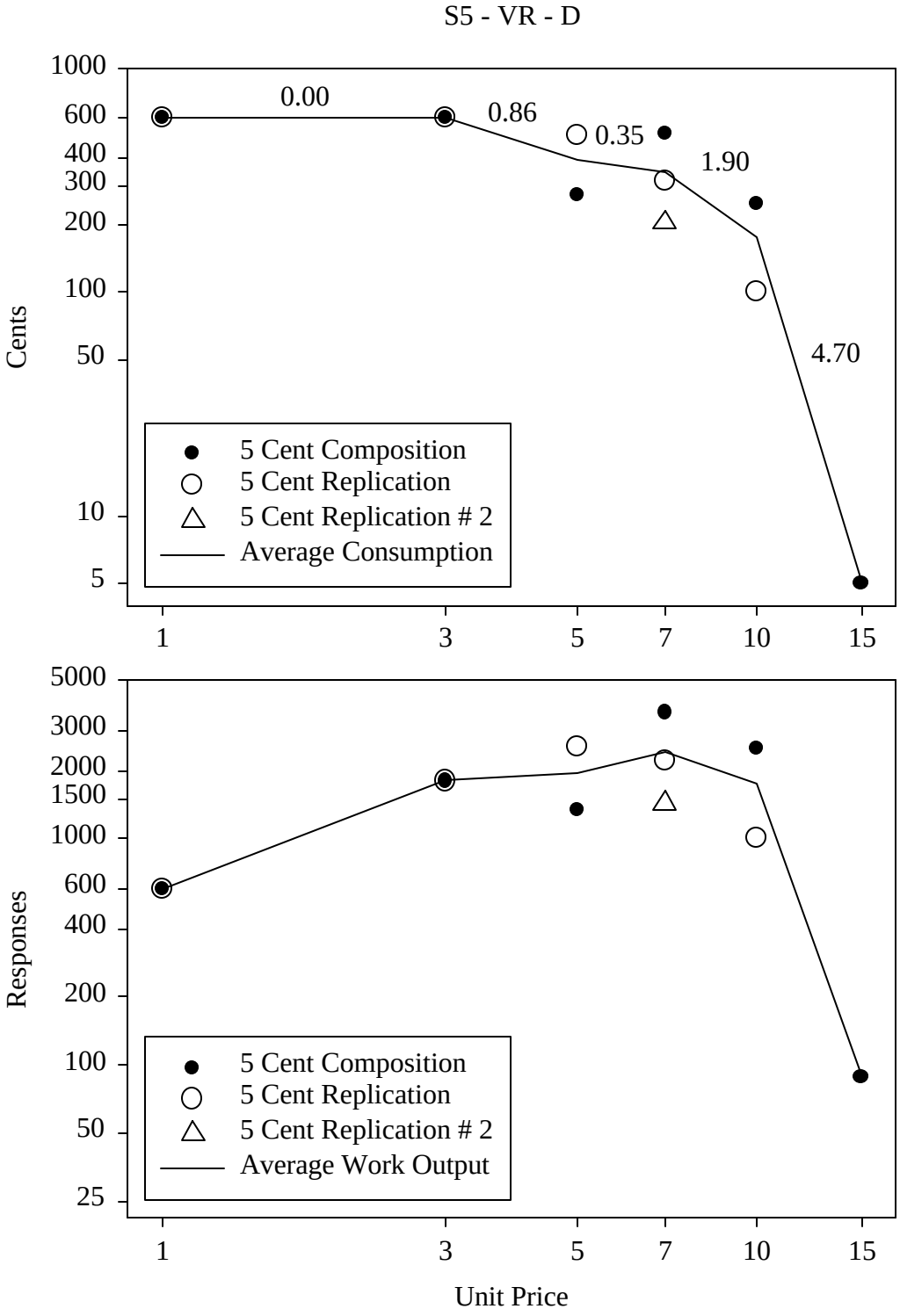

Figure 8. Demand curve (top graph) and work output curve (bottom graph) plotted in log-log units. Lines denote average values of consumption (top graph) and work output (bottom graph). Values on top of the demand curve indicate elasticity coefficients.

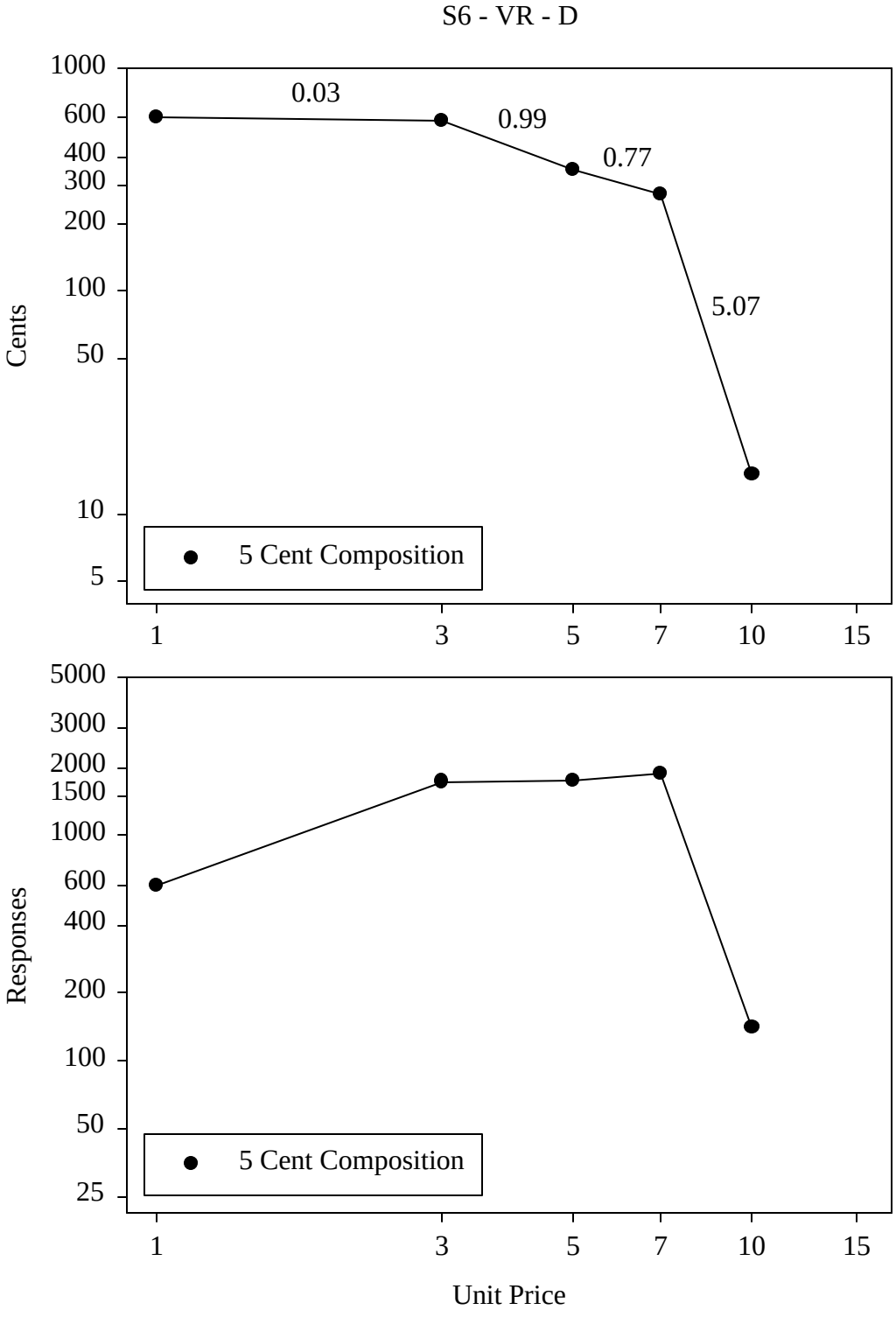

Figure 9. Demand curve (top graph) and work output curve (bottom graph) plotted in log-log units. Lines denote average values of consumption (top graph) and work output (bottom graph). Values on top of the demand curve indicate elasticity coefficients.

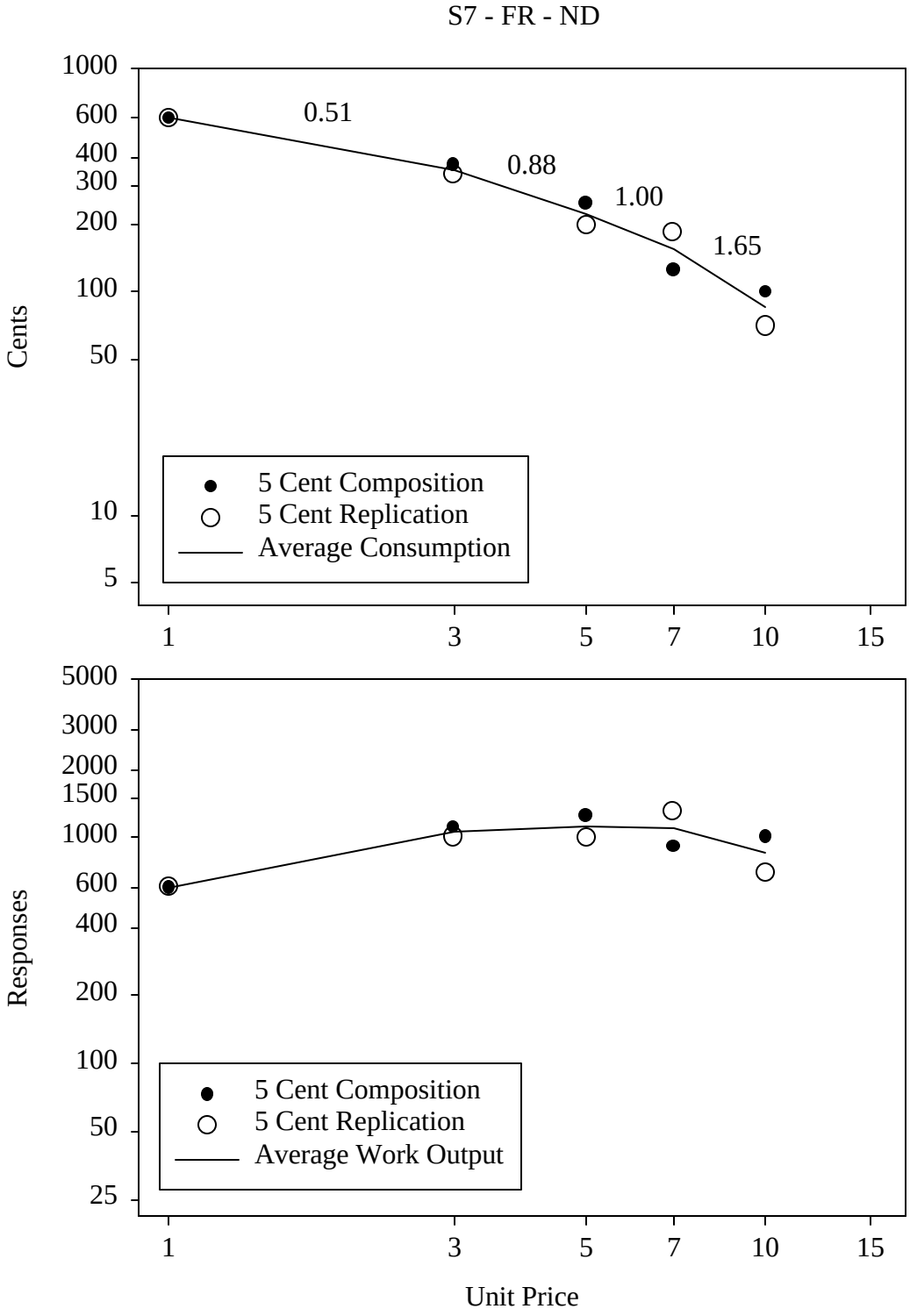

Figure 10. Demand curve (top graph) and work output curve (bottom graph) plotted in log-log units. Lines denote average values of consumption (top graph) and work output (bottom graph). Values on top of the demand curve indicate elasticity coefficients.

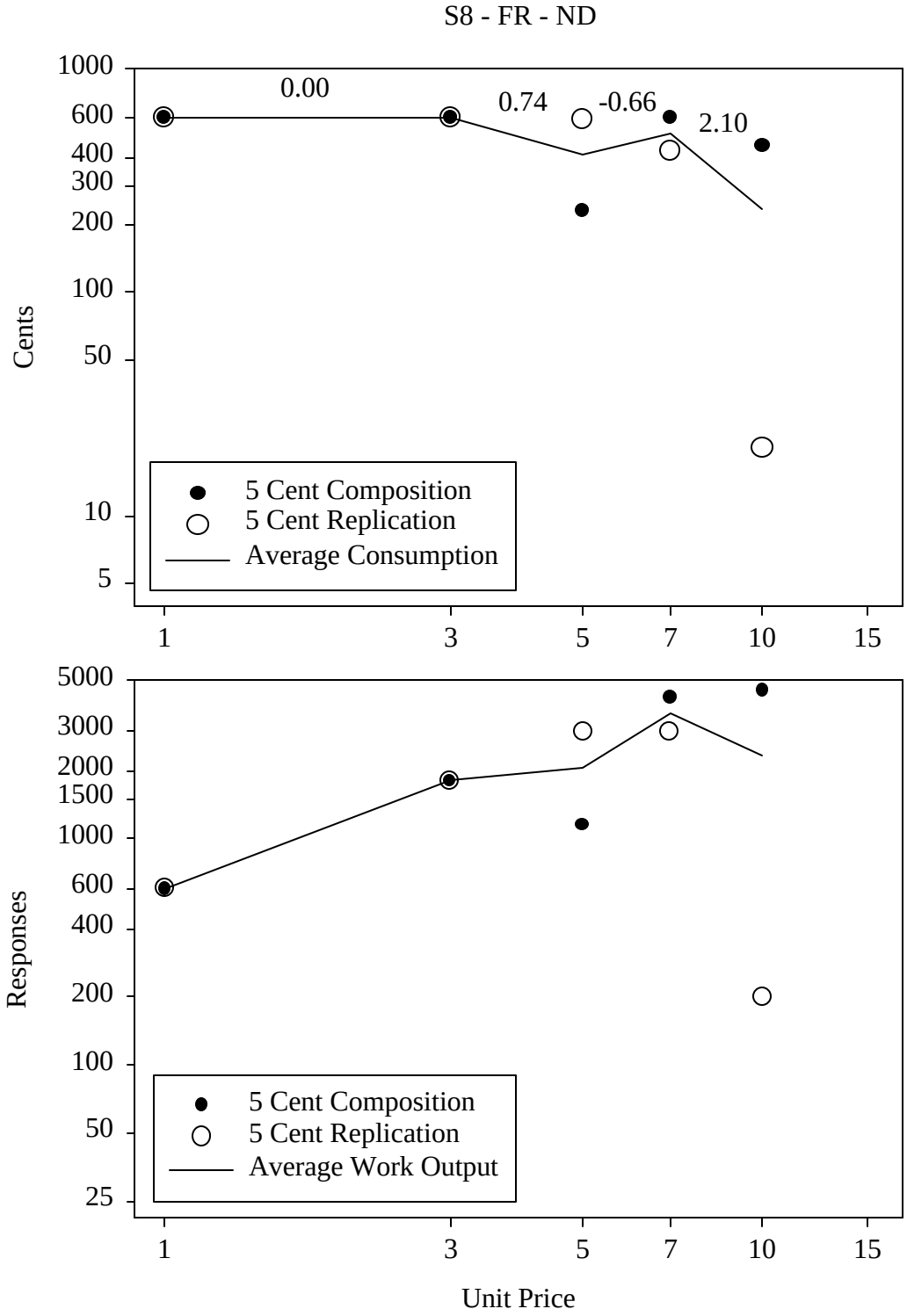

Figure 11. Demand curve (top graph) and work output curve (bottom graph) plotted in log-log units. Lines denote average values of consumption (top graph) and work output (bottom graph). Values on top of the demand curve indicate elasticity coefficients.

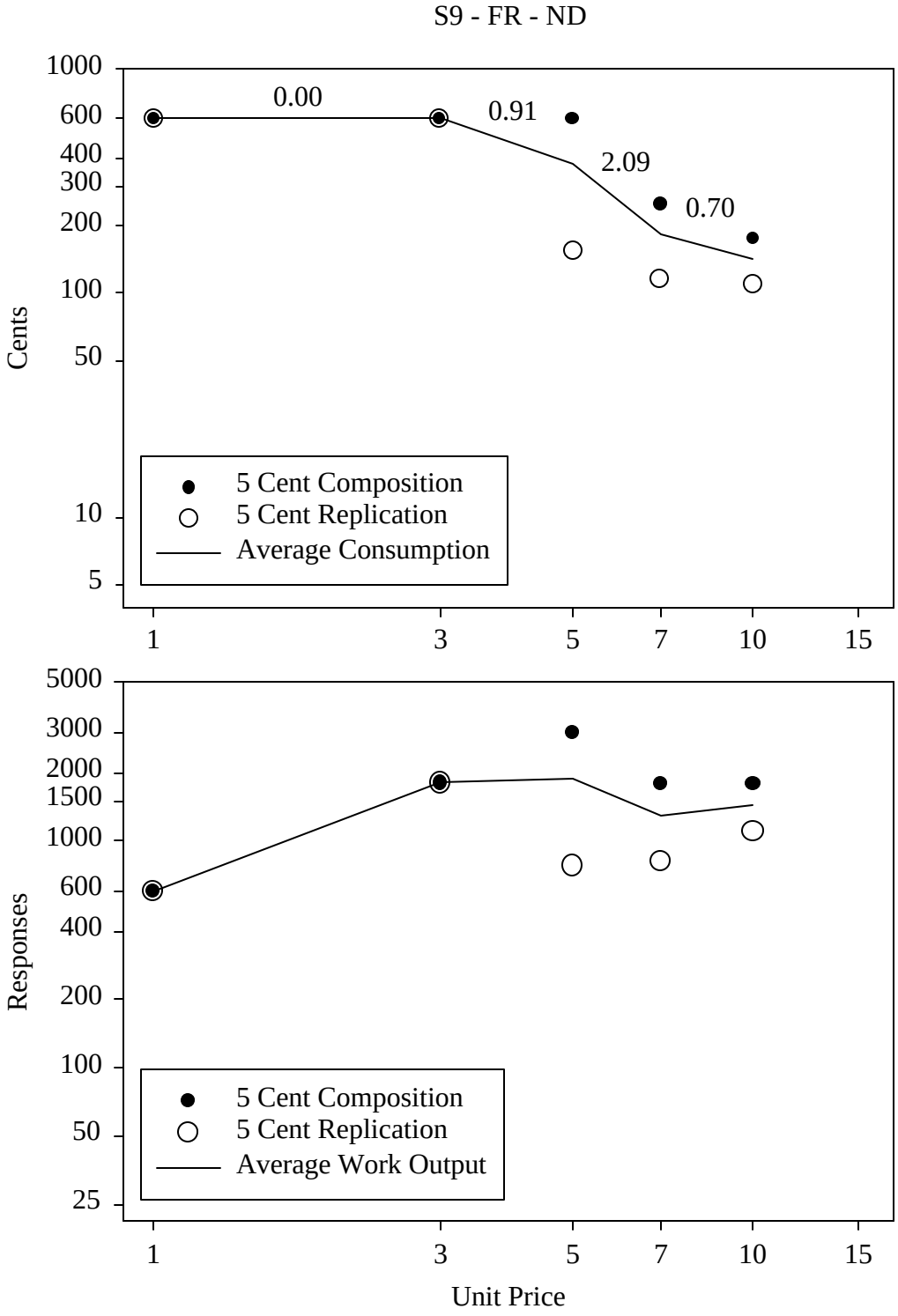

Figure 12. Demand curve (top graph) and work output curve (bottom graph) plotted in log-log units. Lines denote average values of consumption (top graph) and work output (bottom graph). Values on top of the demand curve indicate elasticity coefficients.

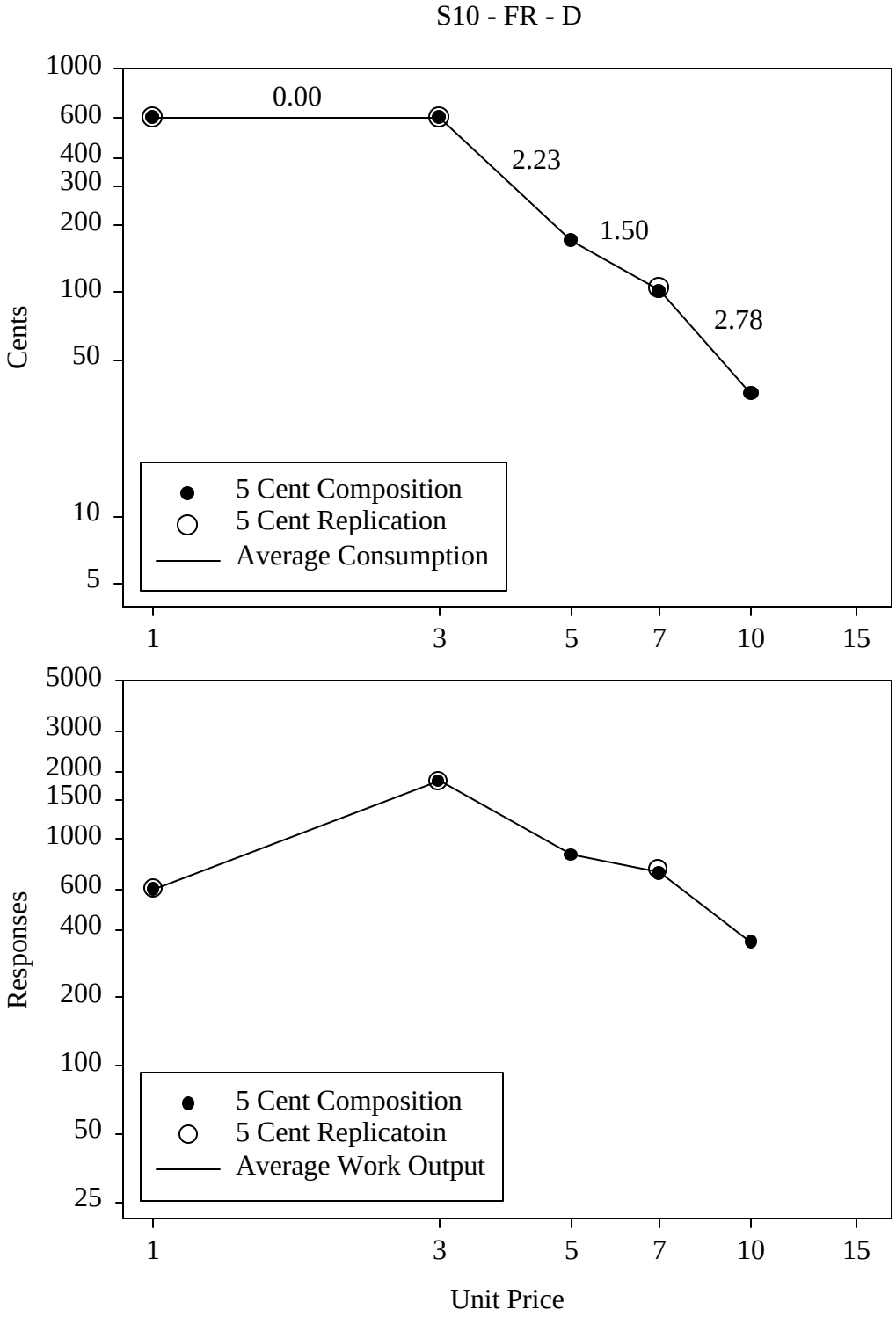

Figure 13. Demand curve (top graph) and work output curve (bottom graph) plotted in log-log units. Lines denote average values of consumption (top graph) and work output (bottom graph). Values on top of the demand curve indicate elasticity coefficients.

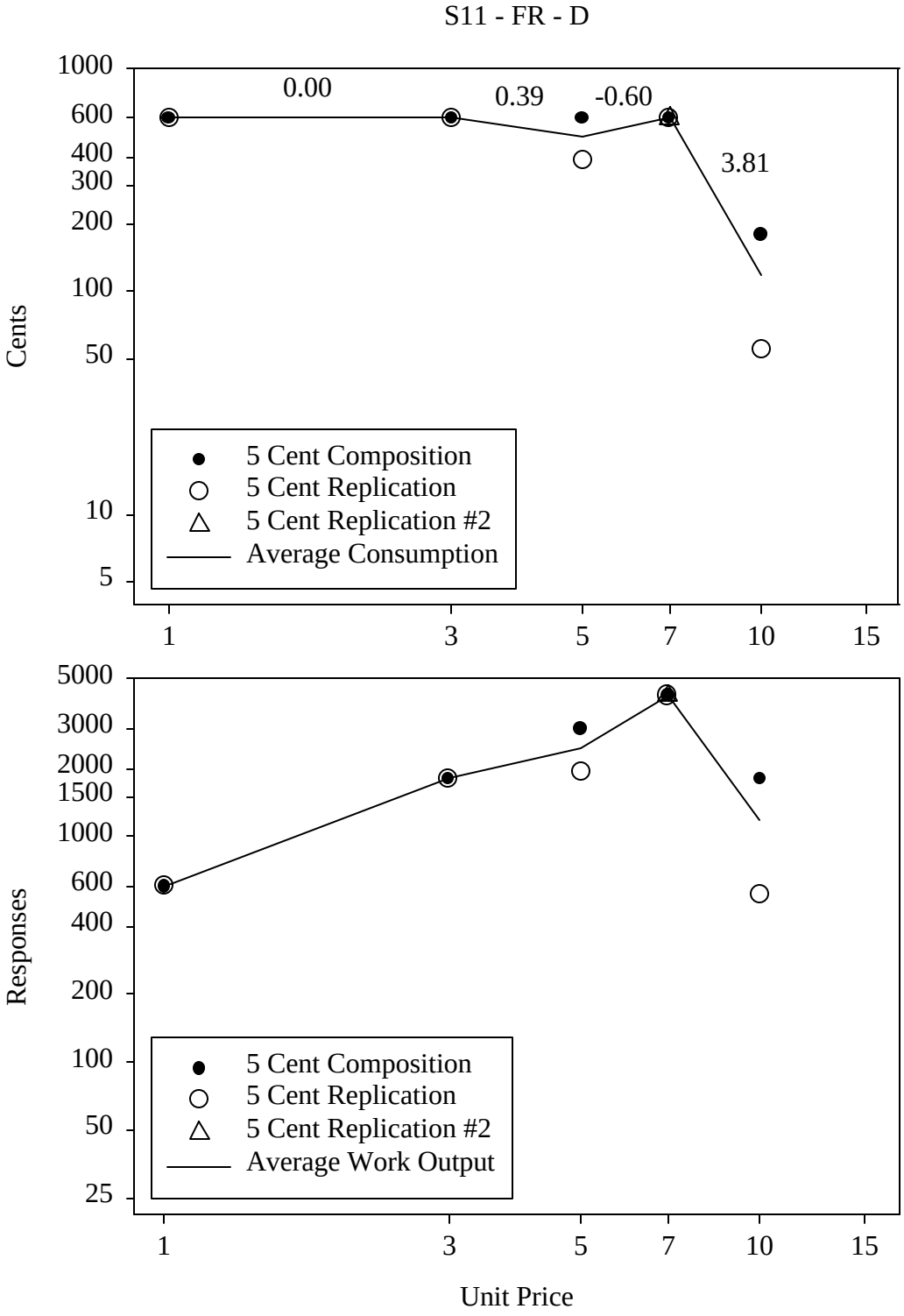

Figure 14. Demand curve (top graph) and work output curve (bottom graph) plotted in log-log units. Lines denote average values of consumption (top graph) and work output (bottom graph). Values on top of the demand curve indicate elasticity coefficients.

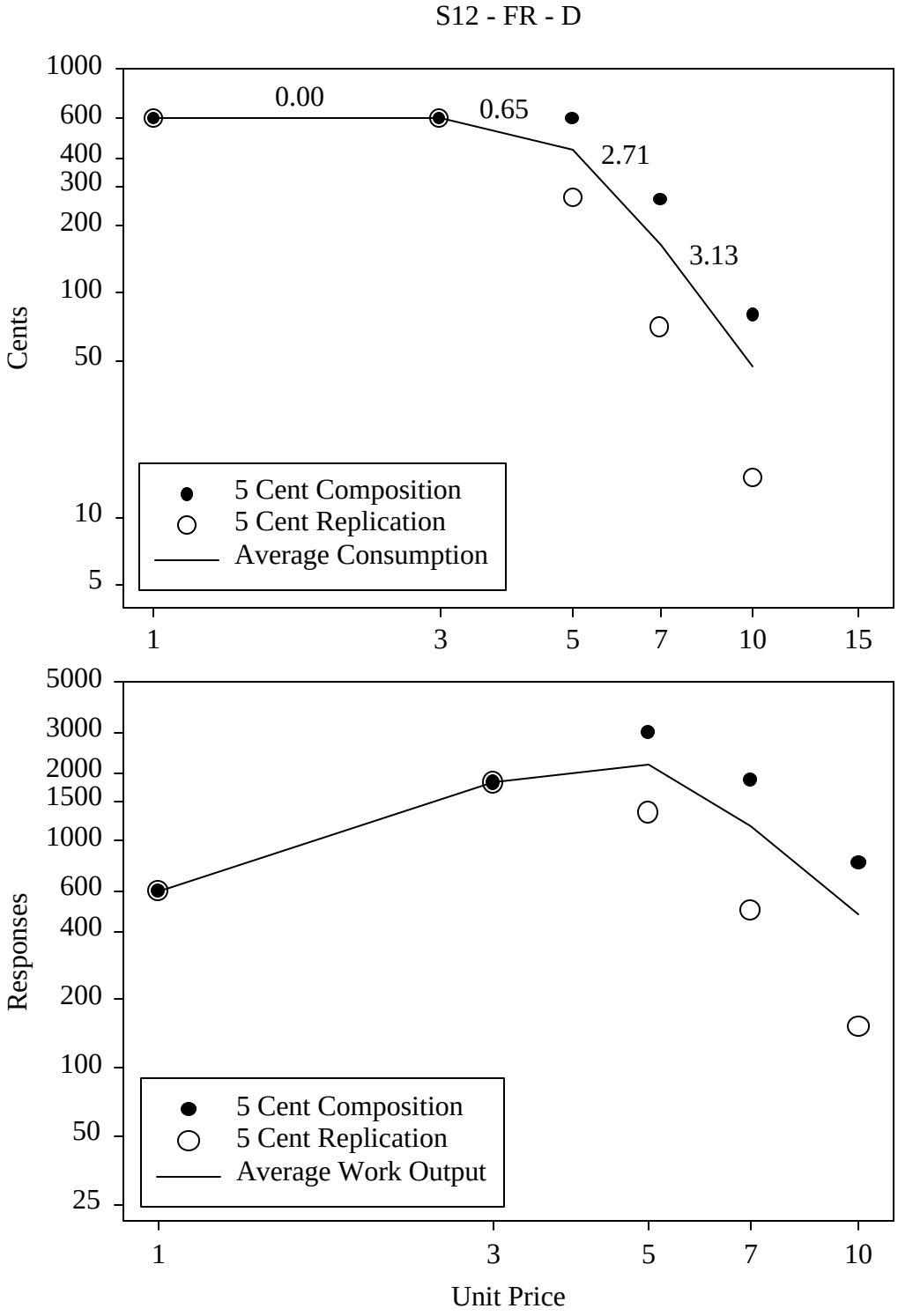

Figure 15. Demand curve (top graph) and work output curve (bottom graph) plotted in log-log units. Lines denote average values of consumption (top graph) and work output (bottom graph). Values on top of the demand curve indicate elasticity coefficients.

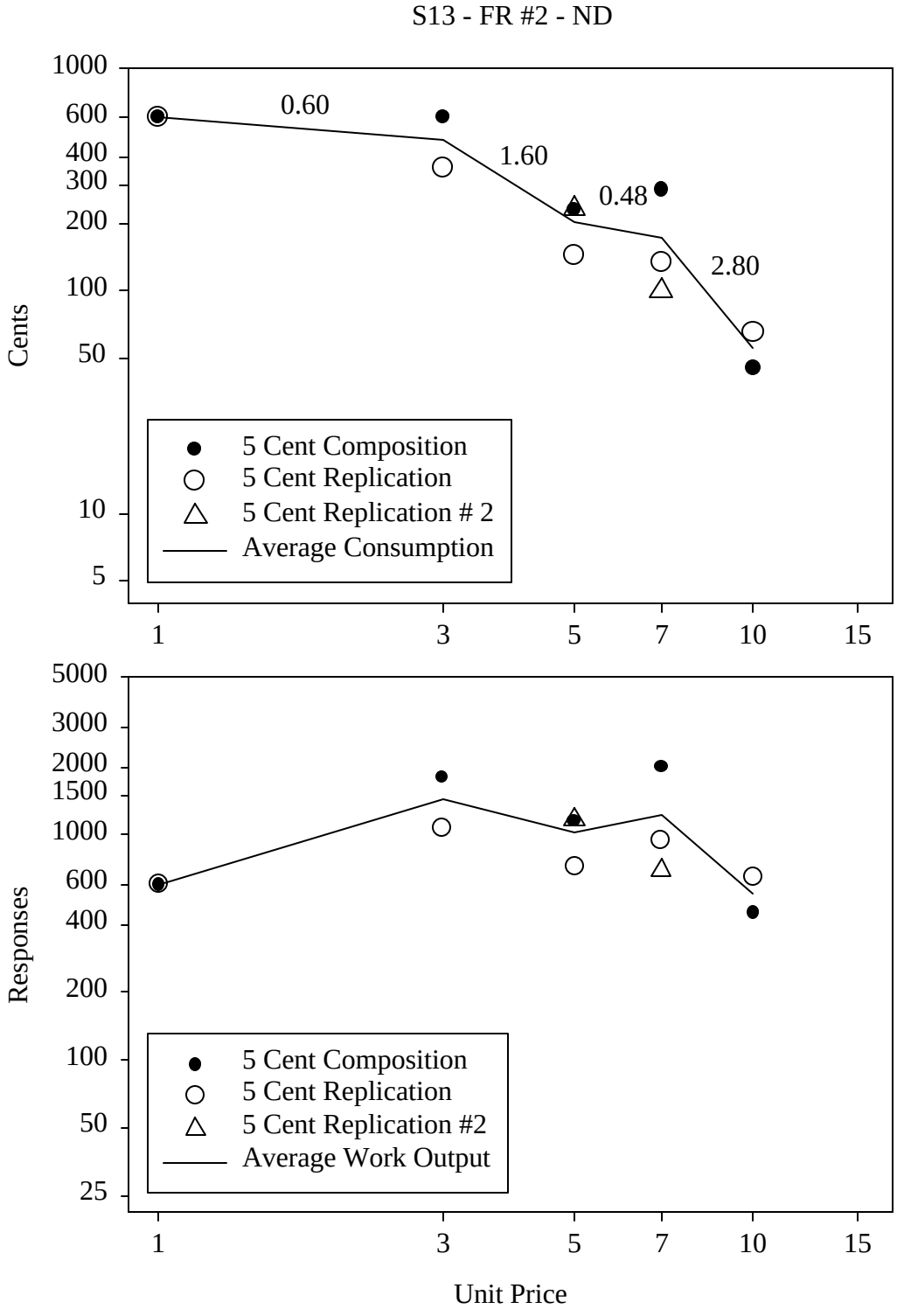

Figure 16. Demand curve (top graph) and work output curve (bottom graph) plotted in log-log- units. Lines denote average values of consumption (top graph) and work output (bottom graph). Values on top of the demand curve indicate elasticity coefficients.

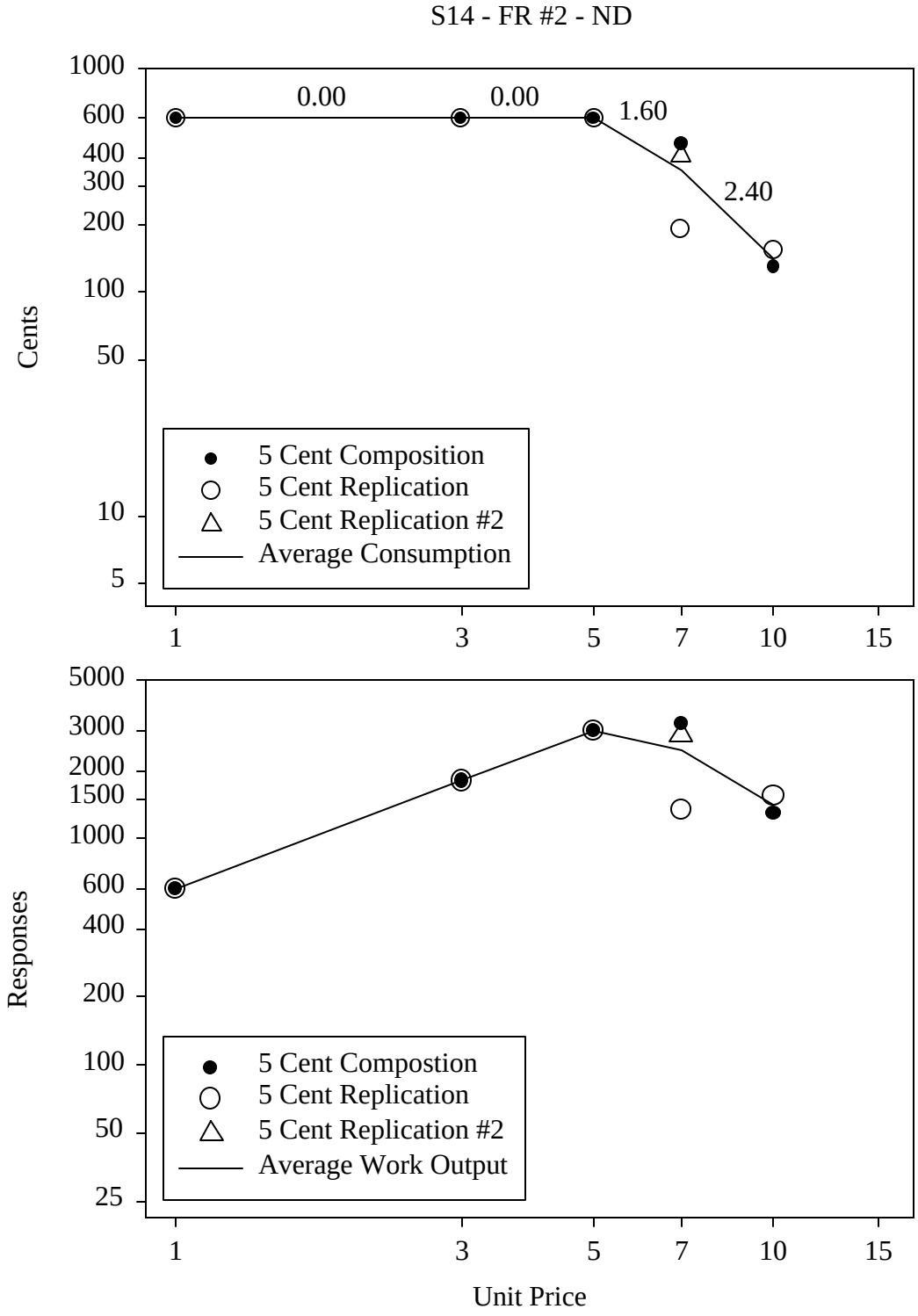

Figure 17. Demand curve (top graph) and work output curve (bottom graph) plotted in log-log units. Lines denote average values of consumption (top graph) and work output (bottom graph) Values on top of the demand curve indicate elasticity coefficients.

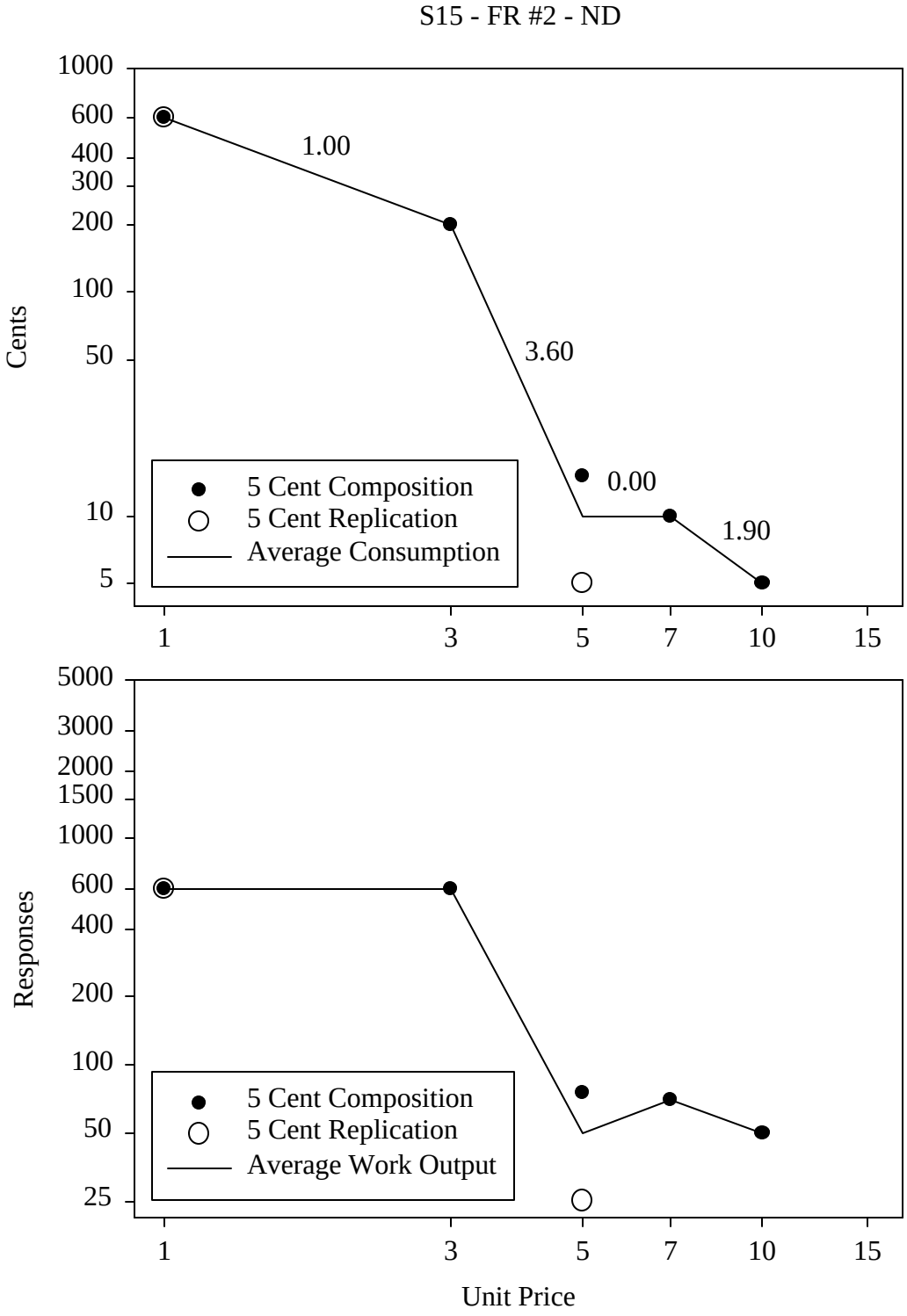

Figure 18. Demand Curve (top graph) and work output curve (bottom graph) plotted in log-log units. Lines denote average values of consumption (top graph) and work output (bottom graph) Values on top of the demand curve indicate elasticity coefficients.

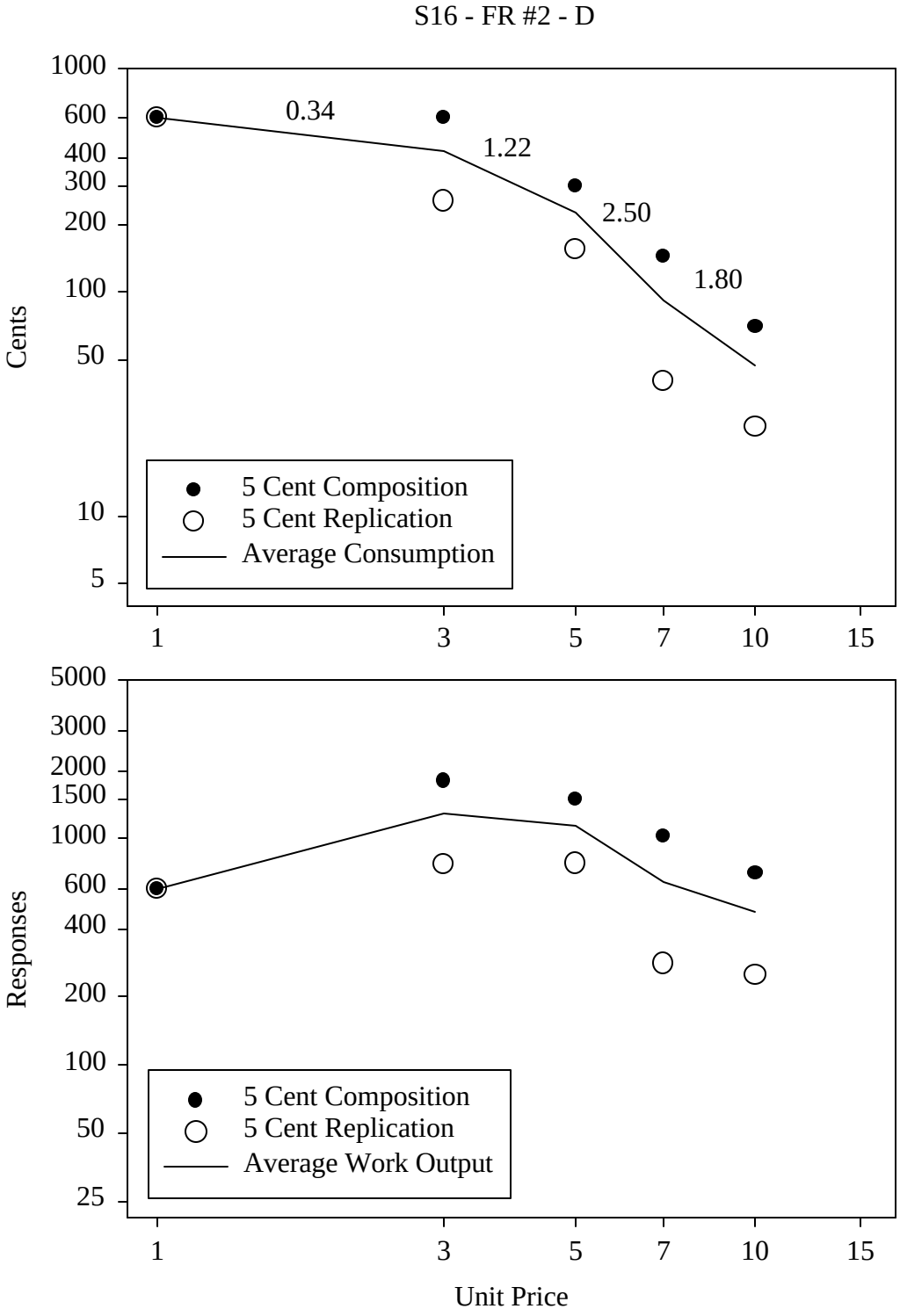

Figure 19. Demand curve (top graph) and work output curve (bottom graph) plotted in log-log units. Lines denote average values of consumption (top graph) and work output (bottom graph). Values on top of the demand curve indicate elasticity coefficients.

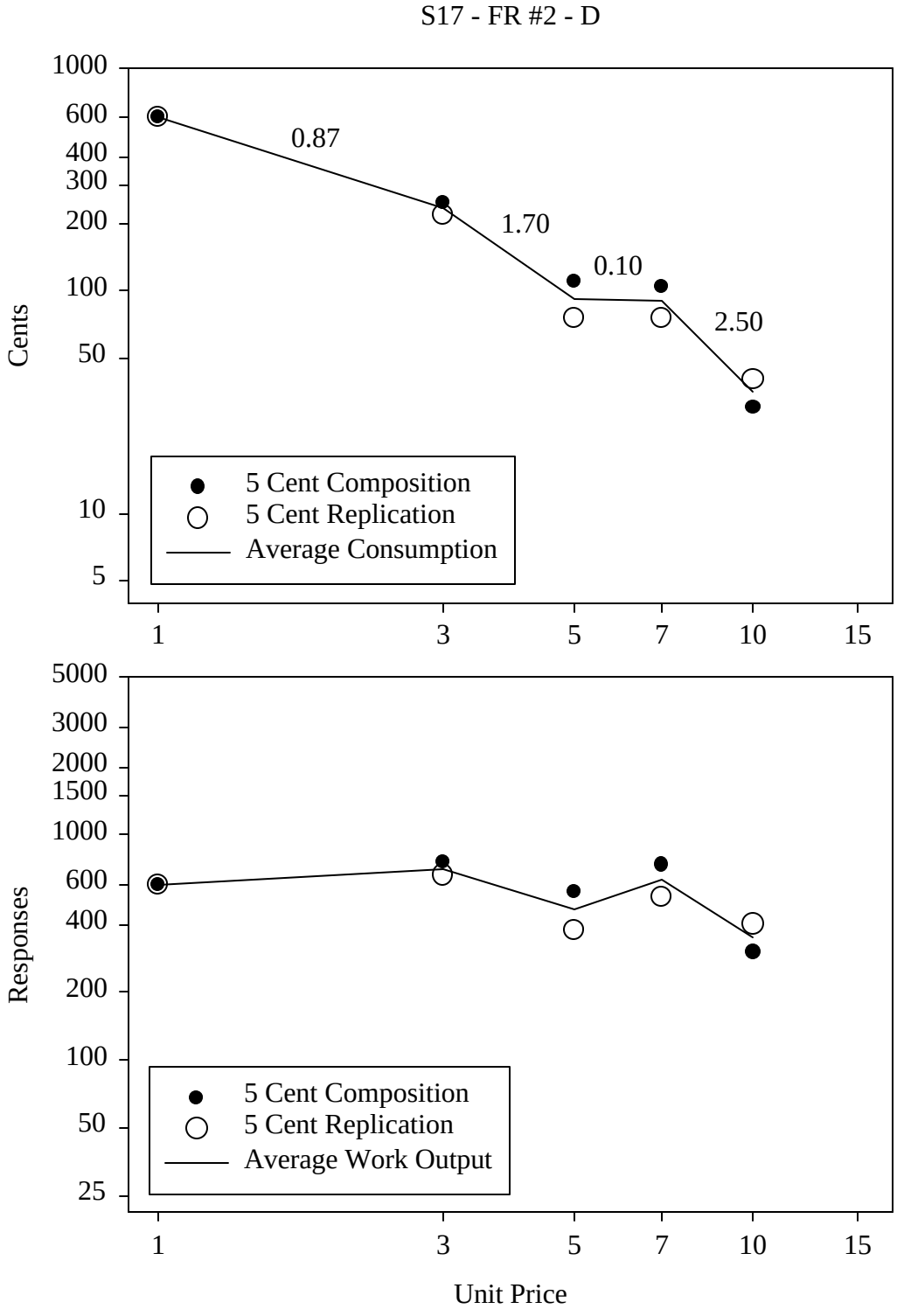

Figure 20. Demand curve (top graph) and work output curve (bottom graph) plotted in log-log units. Lines denote average values of consumption (top graph) and work output (bottom graph) Values on top of the demand curve indicate elasticity coefficients.

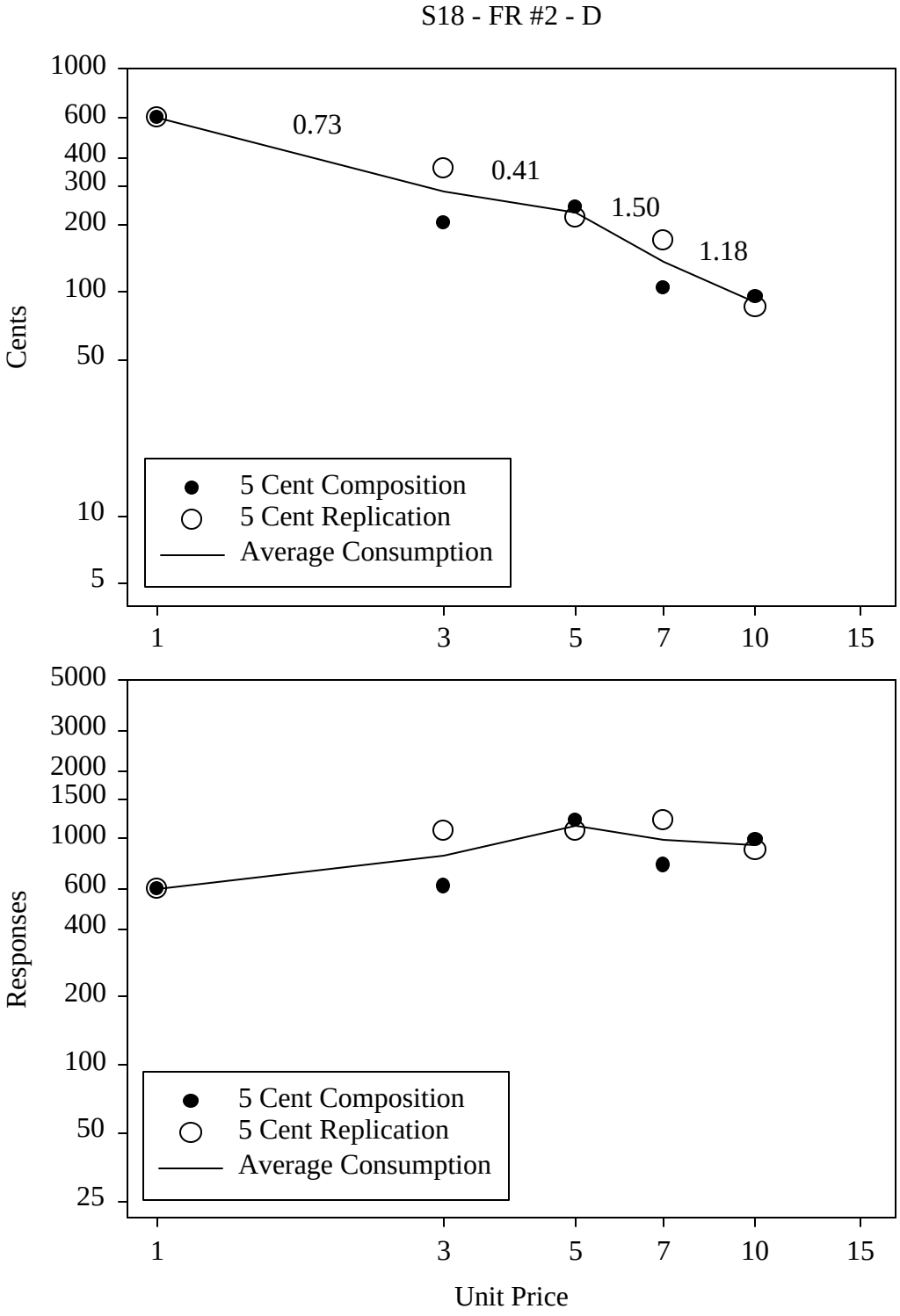

Figure 21. Demand curve (top graph) and work output curve (bottom graph) plotted in log-log units. Lines denote average values of consumption (top graph) and work output (bottom graph). Values on top of the demand curve indicate elasticity coefficients.

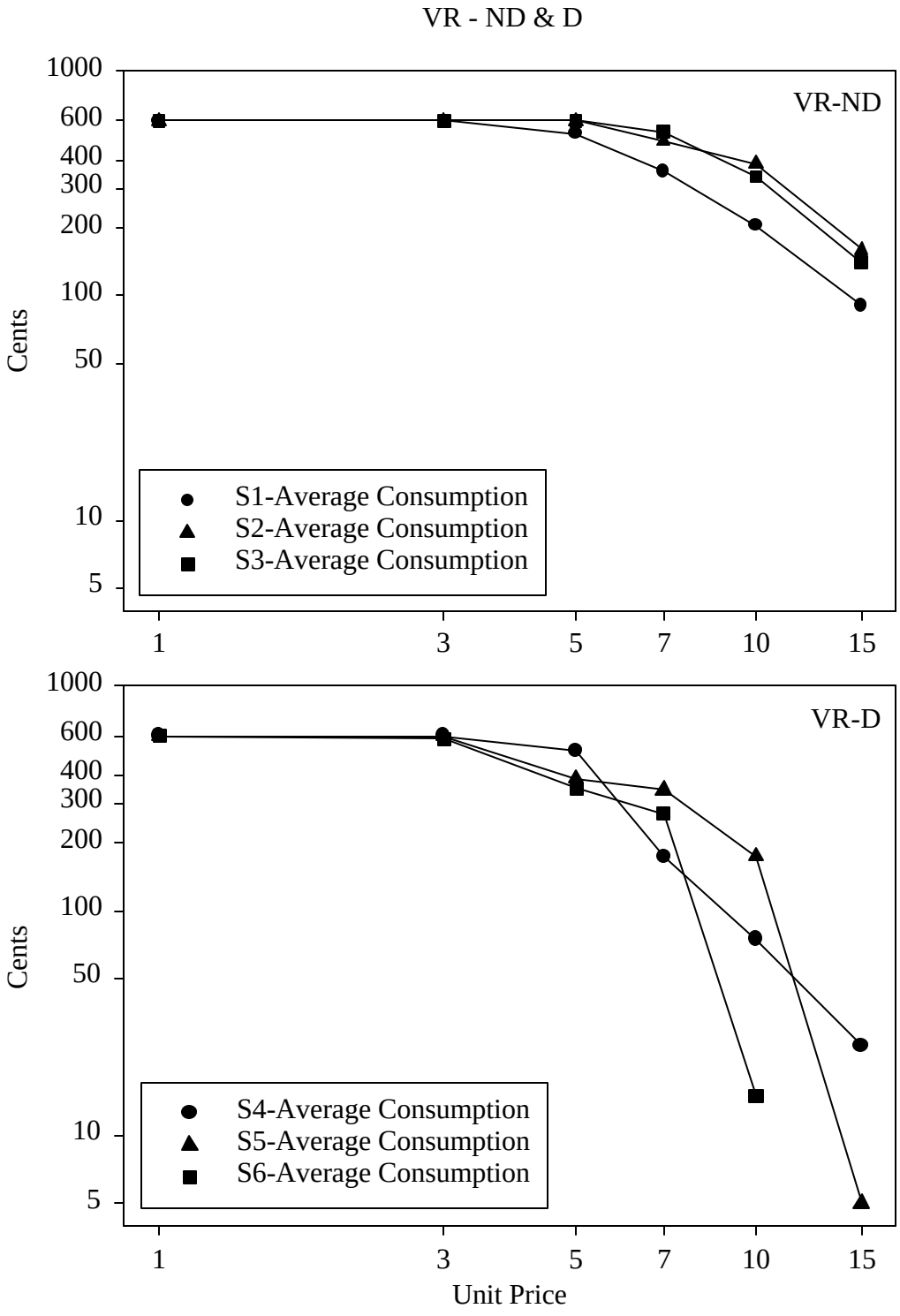

Figure 22. Average consumption for all participants in the VR-ND group (top graph) and the VR-D group (bottom graph).

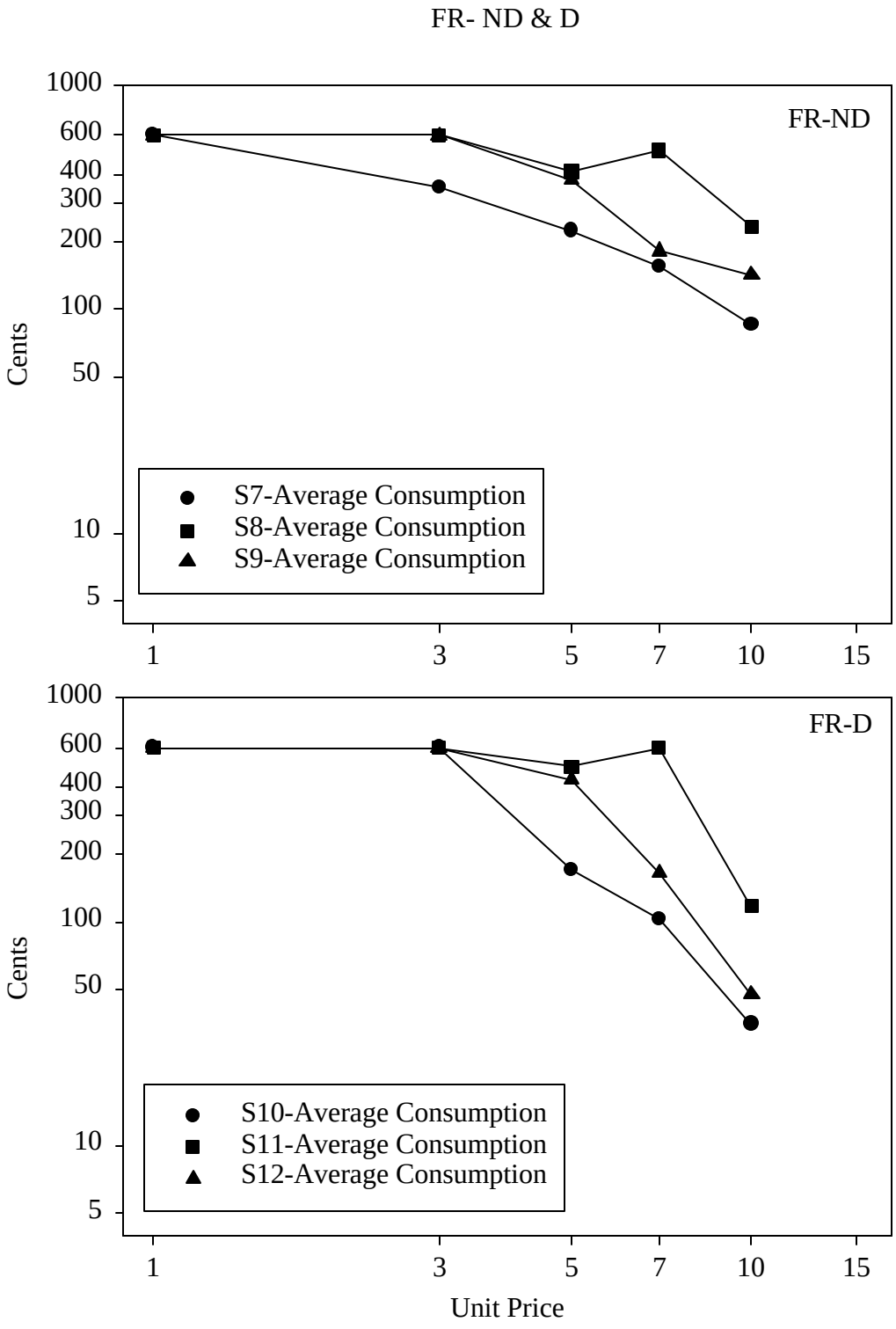

Figure 23. Average consumption for all participants in the FR-ND group (top graph) and the FR-D group (bottom graph).

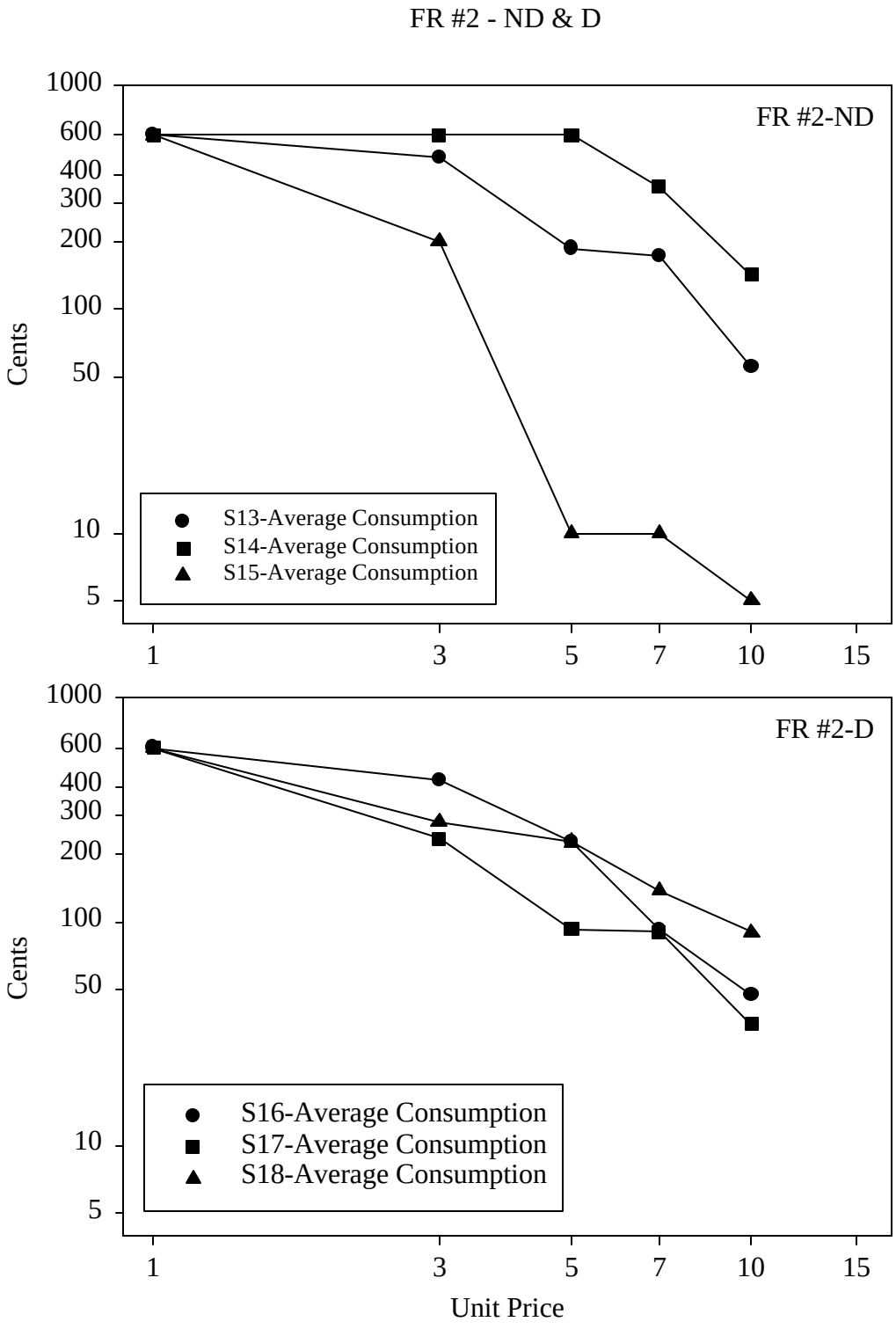

Figure 24. Average consumption for all participants in the FR #2-ND group (top graph) and the FR #2-D group (bottom graph).

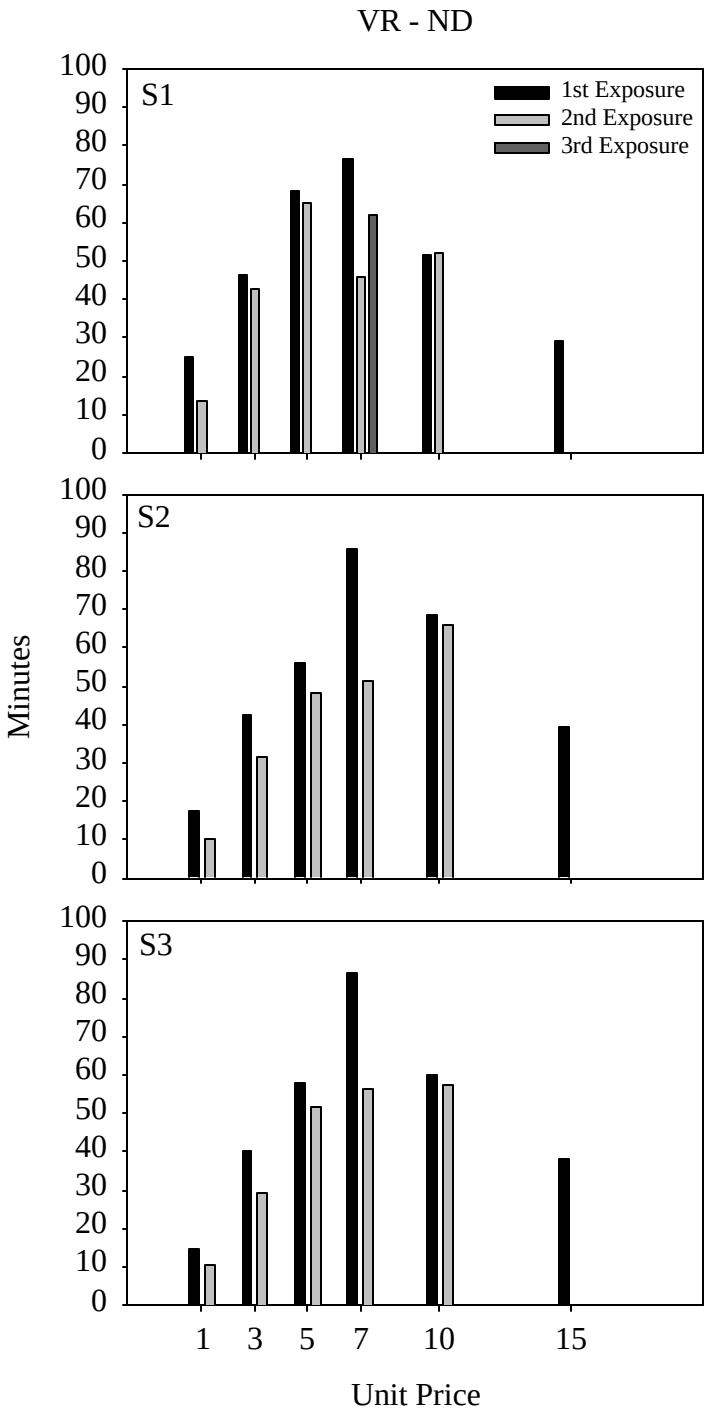

Figure 25. Session durations for first, second, and third exposures to each unit price for all VR-ND participants

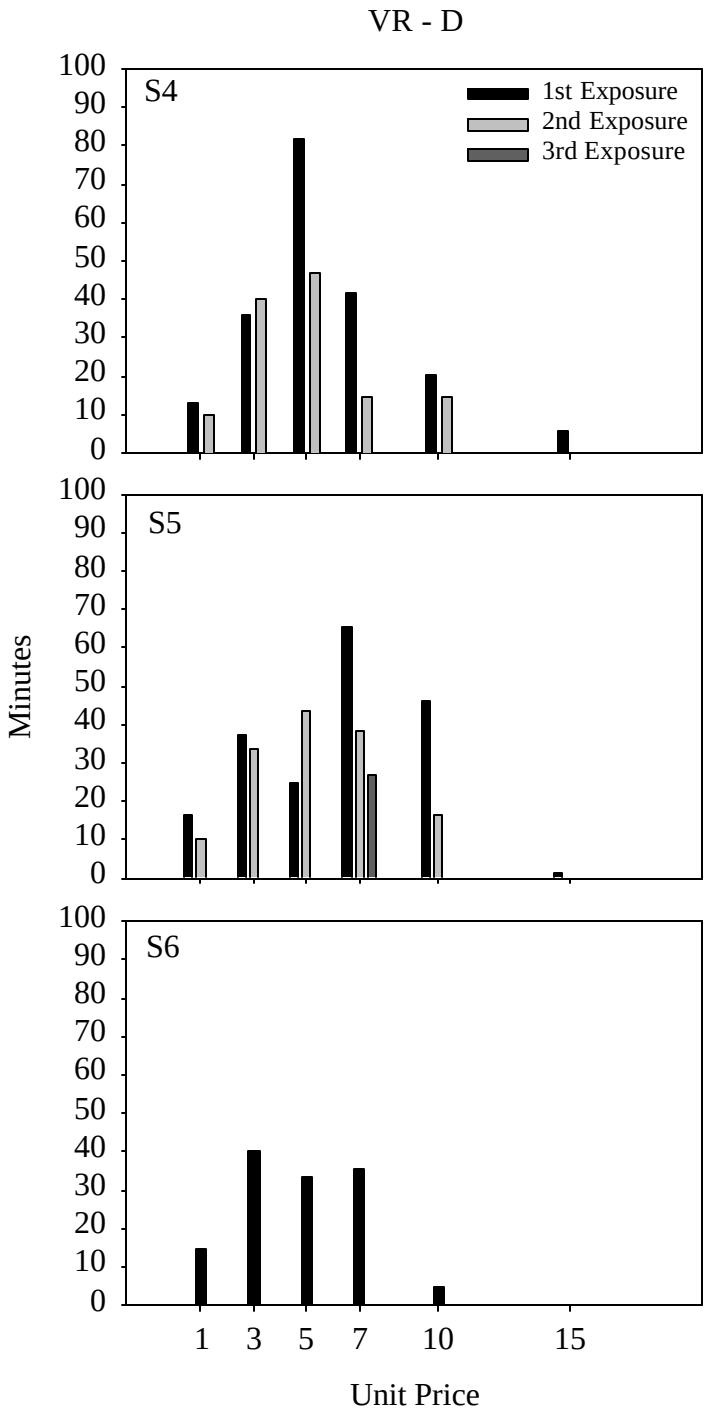

Figure 26. Session durations for first, second, and third exposures to each unit price for all VR-D participants

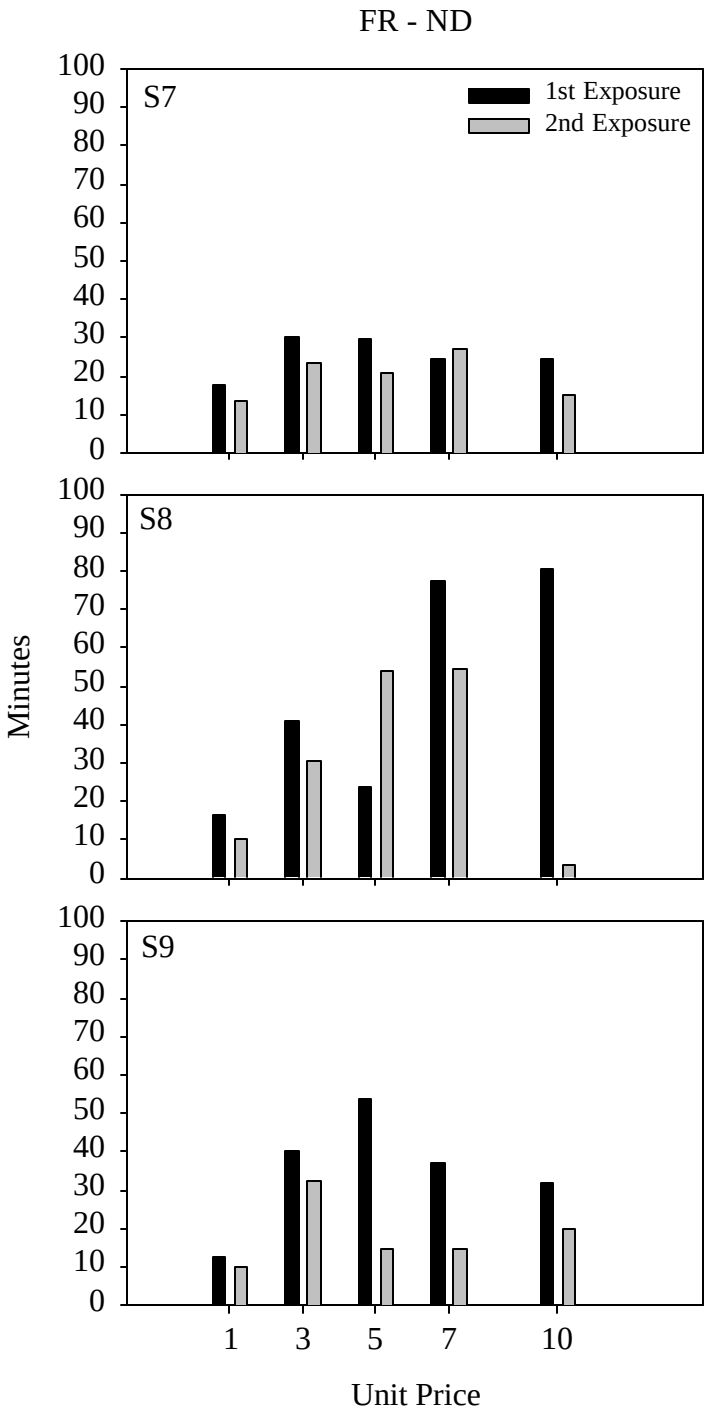

Figure 27. Session durations for first and second exposures to each unit price for all FR-ND participants

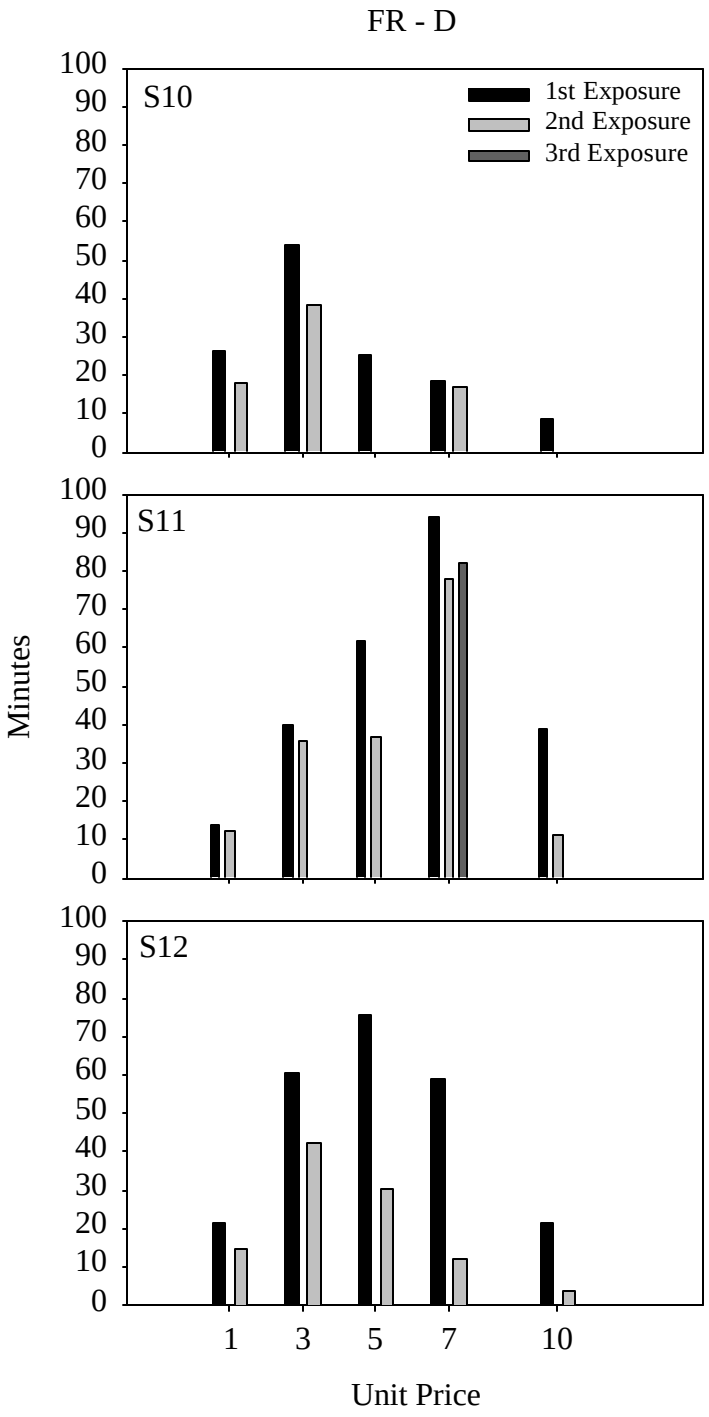

Figure 28. Session durations for first, second, and third exposures to each unit price for all FR-D participants

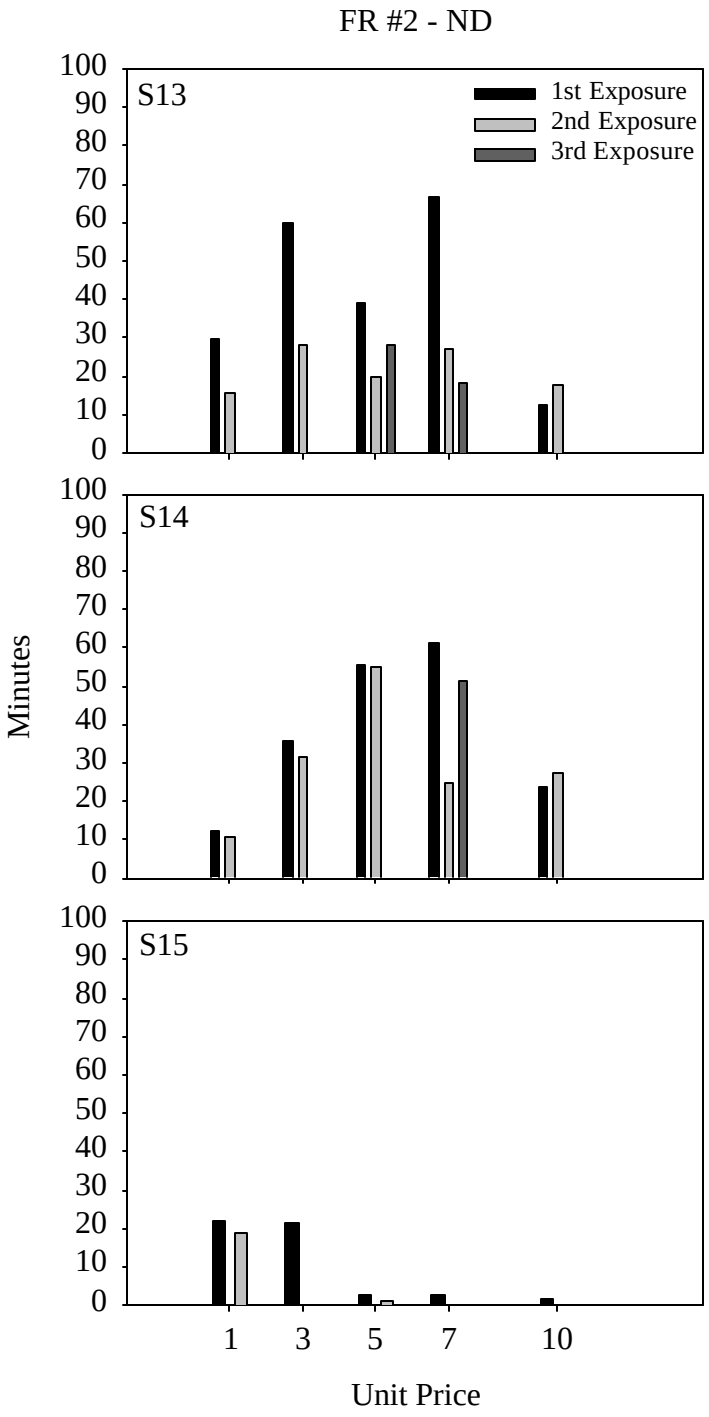

Figure 29. Session durations for first, second, and third exposures to each unit price for all FR #2-D participants

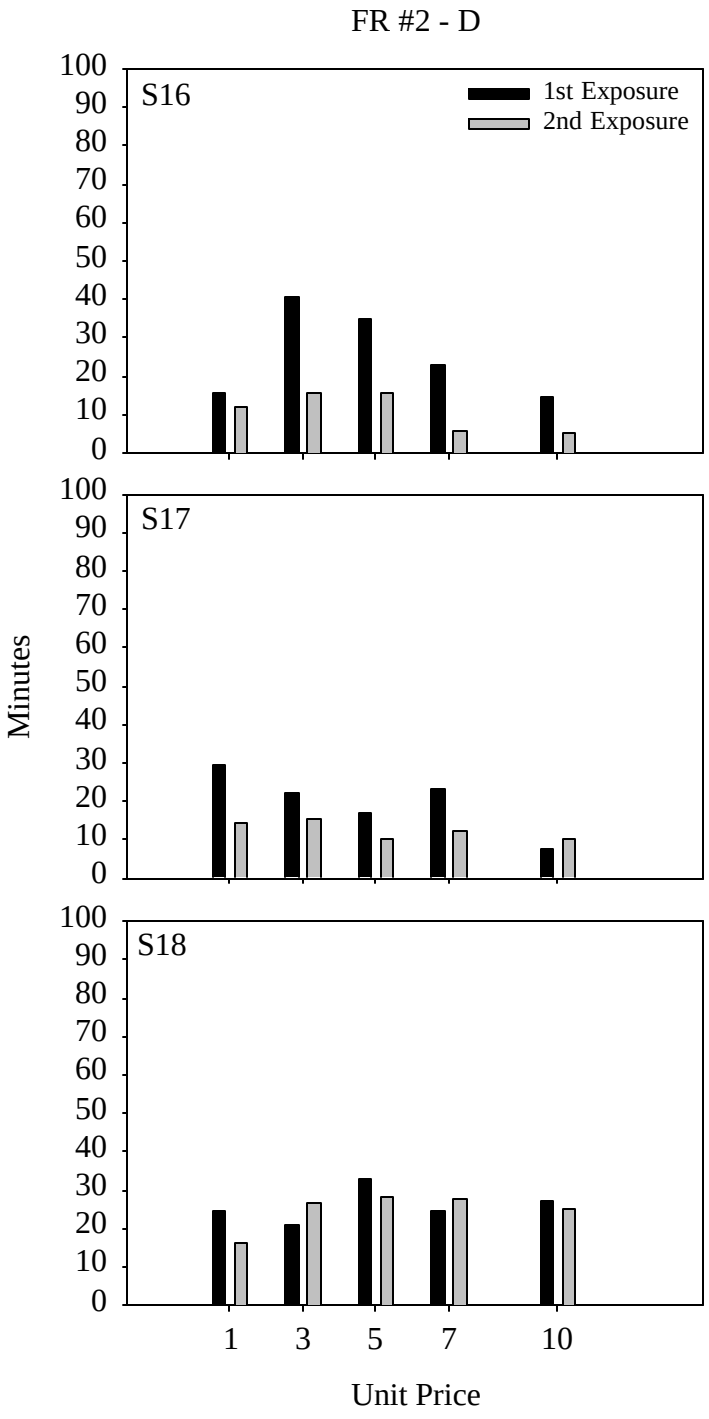

Figure 30. Session durations for first and second exposures to each unit price for all FR-ND participants

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