An Experimental Test of the Lucas Asset Pricing Model

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Abstract

We implement a dynamic asset pricing experiment in the spirit of Lucas (1978) with storable assets and non-storable cash. In one treatment we impose diminishing marginal returns to cash to incentivize consumption-smoothing across periods, while in a second treatment there is no induced motive for trade. In the former case we find that subjects use the asset to smooth consumption though the asset trades at a discount relative to the risk-neutral fundamental price. This under-pricing is a departure from the asset price "bubbles" observed in the large experimental asset pricing literature originating with Smith et al. (1988). In our second treatment with no induced motive for trade (as in the Smith et al. design) assets trade at a premium relative to expected value and shareholdings are highly concentrated. Elimination of asset price uncertainty in additional experimental treatments serves to reinforce these same observations.

JEL Codes: C90, D51, D91, G12.

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1 Introduction

The consumption-based general equilibrium approach to asset pricing, as pioneered in the work of Stiglitz (1970), Lucas (1978) and Breeden (1979), remains a workhorse model in the literature on financial asset pricing in macroeconomics, or *macrofinance*. This approach relates asset prices to individual risk and time preferences, dividends, aggregate disturbances and other fundamental determinants of an asset's value.[1] While this class of theoretical models has been extensively tested using archival field data, the evidence to date has not been too supportive of the models' predictions. For instance, estimated or calibrated versions of the standard model generally under-predict the actual premium in the return to equities relative to bonds, the so-called "equity premium puzzle" (Hansen and Singleton 1983, Mehra and Prescott 1985, Kocherlakota 1996), and the actual volatility of asset prices is typically much greater than the model's predicted volatility based on changes in fundamentals alone – the "excess volatility puzzle" (Shiller 1981, LeRoy and Porter 1981).[2]

A difficulty with testing this model using field data is that important parameters like individual risk and time preferences, the dividend and income processes, and other determinants of asset prices are unknown and have to be calibrated, approximated or estimated in some fashion. An additional difficulty is that the available field data, for example data on aggregate consumption, are measured with error (Wheatley 1988) or may not approximate well the consumption of asset market participants (Mankiw and Zeldes 1991). A typical approach is to specify some dividend process and calibrate preferences using micro-level studies that may not be directly relevant to the domain or frequency of data examined by the macrofinance researcher.

In this paper we follow a different path, by designing and analyzing data from a laboratory experiment that implements a simple version of an infinite horizon, consumption–based general equilibrium model of asset pricing. In the lab we control the income and dividend processes, and can induce the stationarity associated with an infinite horizon and time discounting by introducing an indefinite horizon with a constant continuation probability. We can precisely measure individual consumption and asset holdings and estimate each individual's risk preferences separately from those implied by his market activity, providing us with a clear picture of the environment in which agents are making asset pricing decisions. We can also reliably induce heterogeneity in agent types to create a clear motivation for subjects to engage in trade, whereas the theoretical literature frequently presumes a representative

[1]See, e.g., Cochrane (2005) and Lengwiler (2004) for surveys.

[2]Nevertheless, as Cochrane (2005, p. 455) observes, while the consumption-based model "works poorly in practice... it is in some sense the only model we have. The central task of financial economics is to figure out what are the real risks that drive asset prices and expected returns. Something like the consumption-based model–investor's first-order conditions for savings and portfolio choice–has to be the starting point."

agent and derives equilibrium asset prices at which the equilibrium volume of trade is zero. The degree of control afforded by the lab presents an opportunity to diagnose the causes of specific deviations from theory which are not identifiable using field data alone.

There already exists a literature testing asset price formation in dynamic laboratory economies, but the design of these experiments departs in significant ways from consumption-based macrofinance models.[3] The early experimental literature (e.g., Forsythe, Palfrey and Plott 1982, Plott and Sunder 1982, and Friedman, Harrison and Salmon 1984) instituted markets comprised of several 2-3 period cycles. Each subject was assigned a type which determined his endowment of experimental currency units (commonly called "francs") and asset shares in the first period of a cycle as well as his deterministic type-dependent dividend stream. Francs and assets carried across periods within a cycle. At the end of the cycle's final period, francs were converted to U.S. dollars at a linear rate and paid to subjects, while assets became worthless. Each period began with trade in the asset and ended with dividend payments. The main finding from this literature is that market prices effectively aggregate private information about dividends and tend to converge toward rational expectations values. While such results are in line with the efficient markets view of asset pricing, the primary motivation for exchange owed to heterogeneous dividend values rather than intertemporal consumption-smoothing as in the framework we study.

In later, highly influential work by Smith, Suchanek, and Williams (1988) (hereafter SSW), a simple four-state i.i.d. dividend process was made common for all subjects. A finite number of trading periods ensured that the expected value of the asset declined at a constant rate over time. Unlike the aforementioned heterogeneous dividends literature there was no induced motive for subjects to engage in any trade at all. Nevertheless, SSW observed substantial trade in the asset, with prices starting below the fundamental value then rapidly soaring above it for a sustained duration of time before finally collapsing near the end of the experiment. The "bubble-crash" pattern of the SSW design has been replicated by many authors under a variety of treatment conditions, and has become the primary focus of a large experimental literature on asset price formation (key papers include Porter and Smith (1995), Lei et al. (2001), Dufwenberg, et al. (2005), Haruvy and Noussair (2006), Haruvy et al. (2007), Hussam et al. (2008), Lei and Vesely (2009), Lugovskvy et al. (2011) and Kirchler et al. (2012); for a review of the literature, see chapters 29 and 30 in Plott and

[3]There is also an experimental literature testing the static capital-asset pricing model (CAPM), see, e.g., Bossaerts and Plott (2002), Asparouhova, Bossaerts, and Plott (2003), Bossaerts, Plott and Zame (2007). In contrast to consumption-based asset pricing, the CAPM is a *portfolio-based* approach and presumes that agents have only asset-derived income. Further, the CAPM is not an explicitly dynamic model; laboratory investigations of the CAPM involve repetition of a static, one-period economy. Cochrane (2005) does note that intertemporal versions of the CAPM can be viewed as a special case of the consumption-based approach to asset pricing where the production technology is linear and there is no labor/endowment income.

Smith (2008)). Much attention has been devoted to various means by which the frequency of bubbles can be reduced or even eliminated by researchers using some variant of the SSW design (e.g., adding short sales or futures markets, computing expected values for subjects, implementing a constant dividend, inserting "insiders" who have previously experienced bubbles, using professional traders in place of students as subjects, framing the problem differently, or using different price determination mechanisms).[4] In most of these designs, asset price bubbles turn out to be difficult to eliminate.

Experiments in the SSW tradition share the following features. First, subjects are given a large, one-time endowment (or loan) of francs. Thereafter, an individual's franc balance varies with his asset purchases, sales, and dividends earned on assets held. These individual franc balances carry over from one period to the next over the finite horizon of the market. Following the final period of the market, franc balances are converted into money earnings using a linear exchange rate. This design differs from the sequence–of–budget–constraints faced by agents in standard, infinite horizon intertemporal models; in essence it abstracts from the consumption-smoothing rationale for trade in assets.

By contrast, subjects in our experiment receive an exogenous endowment of francs at the start of each new period, which we interpret as income. Next, a franc-denominated dividend is paid on each share of the asset that a subject holds. Then an asset market is opened, with prices denominated in francs, so that each transaction alters the subject's franc balances. Critically, after the asset market has closed, each subject's end-of-period franc balance is converted to dollars and stored in a private payment account that cannot be used for asset purchases or consumption in any future period of the session, while her assets carry forward to the next period. Thus in our experimental design all francs disappear from the system at the end of each period; that is, they are "consumed," so that assets are durable "trees" and francs are perishable "fruit" in the language of Lucas (1978).[5]

We motivate trade in the asset in our baseline treatment by introducing heterogeneous cyclic incomes and a concave franc-to-dollar exchange rate. Thus long-lived assets become a vehicle for intertemporally smoothing consumption, a critical feature of most macrofinance models which are built around the permanent income model of consumption but one that is

[4]There is some experimental research on asset price determination by Hommes et al. (2005, 2008) that uses a different intertemporal framework – one that exploits the no arbitrage relationship between risky and risk-free assets. These experiments elicit subjects' forecasts of future risky asset prices only and a computer program then uses subjects' forecasts to calculate subjects' optimal current demand for the risky asset. Equating aggregate demand with a fixed supply of the asset yields actual current prices, against which past price forecasts are evaluated. Thus the main goal of subjects in the Hommes et al. experimental design is to correctly forecast prices, while in our framework, the main goal of subjects is to trade (buy and sell) assets so as to implement their intertemporal optimization (consumption-smoothing) plan.

[5]Notice that francs play a dual role as "consumption good" and "medium of exchange" within a period, but assets are the only *intertemporal* store of value in our design.

absent from the experimental asset pricing literature. In our alternative "linear" treatment, the franc-to-dollar exchange rate is made linear as in SSW-type designs. Since the dividend process is common to all subjects there is no induced reason for subjects to trade in the asset at all in this second, linear treatment, a design feature which serves to connect our baseline macrofinance economy with the laboratory asset market design of SSW.

Most consumption-based asset pricing models posit stationary, infinite planning horizons, while most dynamic asset pricing experiments impose finite horizons with declining asset values. We induce stationarity by implementing an indefinite horizon in which assets become worthless at the end of each period with a known constant probability, a standard approach in a wide range of economic experiments. If subjects are risk-neutral expected utility maximizers, our indefinite horizon economy features the same steady state equilibrium price and shareholdings as its infinite horizon constant time discounting analogue.

We also consider the consequences of departures from risk-neutral behavior. Our analysis of this issue is both theoretical and empirical. Specifically, we elicit a measure of risk tolerance from subjects in most of our experimental sessions using the Holt-Laury (2002) paired lottery choice instrument. To our knowledge no prior study has seriously investigated risk preferences in combination with a multi-period asset pricing experiment.

While our experimental design is mainly intended to serve as a bridge between the experimental asset pricing and macrofinance literatures, it also has some relevance for laboratory research on intertemporal consumption-smoothing. Experimental investigations of intertemporal consumption smoothing (without tradeable assets) is the focus of several papers: Hey and Dardanoni (1988), Noussair and Matheny (2000), Ballinger et al. (2003) and Carbone and Hey (2004). A main finding from that literature is that subjects have difficulty learning to intertemporally smooth their consumption in the manner prescribed by the solution to a dynamic optimization problem; in particular, current consumption appears to be too closely related to current income relative to the predictions of the optimal consumption function. By contrast, in our experimental design where intertemporal consumption-smoothing must be implemented by buying and selling assets at market-determined prices, we find strong evidence that subjects are able to smooth consumption in a manner that is qualitatively (if not quantitatively) similar to the dynamic, equilibrium solution. Our finding in support of consumption-smoothing is likely owing to the considerably simpler and non-stochastic income process that we use in our design; subjects in our experiment need to learn only how to repeatedly smooth consumption across two, perfectly known and alternating income states (high and low). By contrast, in the experimental consumption-smoothing literature, subjects are confronted with smoothing a stochastic income process over a much longer horizon (e.g., lifecycle horizons of 25 or more periods as in Carbone and Hey (2004) and Ballinger et al. (2003)). As a consequence, subjects have fewer opportunities to learn how to smooth consumption over this longer horizon than in our design, where subjects have multiple opportunities to smooth consumption over the indefinitely repeated two-period income process. Our different finding on consumption-smoothing may also be related to the endogenous determination of asset prices (the savings vehicle for consumption smoothing) in our design and so we also consider follow-up treatments where asset prices are exogenously given, but where subjects remain incentivized to smooth consumption. In the latter case, we find evidence of even stronger consumption-smoothing.

The main findings of our experiment can be summarized as follows. First, the stochastic horizon in the linear exchange rate treatment (where, as in SSW, there is no induced motive to trade the asset) does not suffice to eliminate asset price "bubbles." Indeed, we often observe sustained prices above fundamentals in this environment; on average, prices are 32% above the asset's fundamental value in these sessions. However, the frequency, magnitude, and duration of asset price bubbles are significantly reduced in our concave exchange rate treatment. In this concave treatment, assets trade at an average discount relative to their risk-neutral fundamental price of 24% (a fact which suggests a modified design might help to identify an equity premium, although the lack of a risk-free bond prevents us from doing so here). The higher prices in the linear exchange rate economies are driven by a concentration of shareholdings among the most risk-tolerant subjects in the market as identified by the Holt-Laury measure of risk attitudes. By contrast, in the concave exchange rate economies, most subjects actively traded shares in each period so as to smooth their consumption in the manner predicted by theory; consequently, shareholdings were much less concentrated. Thus market thin-ness and high prices appear to be endogenous features of our more naturally speculative treatment. We conclude that the frequency, magnitude, and duration of asset price bubbles can be reduced by the presence of an incentive to intertemporally smooth consumption in an otherwise identical economy, a key feature of most dynamic asset pricing models absent from the SSW design.

In addition to reporting on the outcome of our asset market experimental design, we also conduct some individual-choice experiments which we use to better understand individual consumption and savings decisions. In these individual choice experiments, we remove all uncertainty about the price of the asset, by letting subjects buy or sell the asset at a fixed and known price. Hence there is no need for a market determination of that price. Thus, in these individual choice experiments, the only uncertainty each subject faces is the duration of the planning horizon, which together with endowments and utility functions remain the same as in the market experiment. We find that the removal of price uncertainty serves to reinforce or even strengthen the main findings from our market experiment, namely that individuals facing a concave exchange rate use the asset to intertemporally smooth their consumption while those facing a linear exchange rate do not.

In concurrent experimental research, Asparouhova et al. (forthcoming) study a Lucas economy in which there are short-lived francs and two long-lived assets: trees with stochastic dividends and risk-free (console) bonds. Rather than induce consumption-smoothing through a concave exchange rate, the authors pay subjects for cash holdings only during the terminal period of the indefinite sequence, and thus they rely on innate subject risk aversion to smooth consumption; i.e., a risk-averse subject in their design should avoid ending a period with too little cash in the event that period is terminal.[6] Thus Asparouhova et al. use endogenous consumption-smoothing to investigate important questions in finance like the equity premium puzzle and the covariation of financial returns with aggregate wealth, while we focus on demonstrating the comparative static impact of consumption-smoothing when such incentives are exogenously weak or strong. Our focus also differs from Asparouhova et al. in that we are interested in understanding differences in behavior between the consumption-based, Lucas asset pricing environment and in the asset pricing environment studied by experimentalists beginning with Smith et al. (1988) where there are no induced motivations to trade in the asset, and indeed, such an environment comprises one of the main treatments of our study. Like Asparouhova et al. we find some qualified support for the predictions of the Lucas asset pricing model in that price realizations are not far from competitive equilibrium levels and most subjects in our concave treatment are using the asset to intertemporally smooth their consumption.

2 The Lucas asset pricing framework

In this section we first describe a heterogeneous agent version of Lucas's (1978) infinite horizon economy. We then present the indefinite horizon version we actually implement in the laboratory, and demonstrate steady state equilibrium equivalence between the two models under the assumption that subjects are risk-neutral expected utility maximizers. Later, in section 5, we consider how the model is impacted by departures from risk neutrality.

2.1 The infinite horizon economy

Time t is discrete, and there are two agent types, $i = 1, 2$, who participate in an infinite sequence of markets. There is a fixed supply of an infinitely durable asset (trees) and shares which yield a dividend (fruit) in amount d_t per period. Dividends are paid in units of the single non-storable consumption good at the beginning of each period. Let s_t^i denote

[6] To address the concern about potential wealth effects in our design, we note that in an indefinite horizon experiment, Sherstyuk, Tarui, and Saijo (2013) find no evidence that subjects behave differently when paid only for the terminal period rather than begin paid for all periods.

the number of asset shares agent i owns at the beginning of period t, and let p_t be the price of an asset share in period t. In addition to dividend payments, agent i receives an exogenous endowment of the consumption good y_t^i at the beginning of every period. His initial endowment of shares is denoted s_1^i.

Agent i faces the following objective function:

$$\max_{\{c_t^i\}_{t=1}^{\infty}} E_1 \sum_{t=1}^{\infty} \beta^{t-1} u(c_t^i),$$

subject to

$$c_t^i \leq y_t^i + d_t s_t^i - p_t \left(s_{t+1}^i - s_t^i \right)$$

for $t \geq 1$ and a transversality condition ruling out non-fundamental solutions:

$$\lim_{T \to \infty} E_t \beta^T u'(c_{t+T}^i) p_{t+T} = 0.$$

Here, c_t^i denotes consumption of the single perishable good by agent i in period t, $u(\cdot)$ is a strictly monotonic, strictly concave, twice differentiable utility function that is common to all i and $\beta \in (0,1)$ is the common period discount factor. The budget constraint is satisfied with equality by monotonicity. We will permit neither borrowing nor short sale constraints in the experiment, though the economy will be parameterized in such a way that these restrictions only bind out-of-equilibrium. Substituting the budget constraint for consumption in the objective function, and using asset shares as the control, we can restate the problem as:

$$\max_{\{s_{t+1}^i\}_{t=1}^{\infty}} E_1 \sum_{t=1}^{\infty} \beta^{t-1} u(y_t^i + d_t s_t^i - p_t(s_{t+1}^i - s_t^i)).$$

The first order condition for each time $t \geq 1$, suppressing agent superscripts for notational convenience, is:

$$u'(c_t) p_t = E_t \beta u'(c_{t+1})(p_{t+1} + d_{t+1}).$$

Rearranging we have the asset pricing equation:

$$p_t = E_t \mu_{t+1} (p_{t+1} + d_{t+1}) \tag{1}$$

where $\mu_{t+1} = \beta \frac{u'(c_{t+1})}{u'(c_t)}$, a term that is referred to variously as the stochastic discount factor, the pricing kernel, or the intertemporal marginal rate of substitution. If we assume, for example, that $u(c) = \frac{c^\gamma}{1-\gamma}$ (the commonly studied CRRA utility), we have $\mu_{t+1} = \beta \left(\frac{c_t}{c_{t+1}} \right)^\gamma$. Notice from equation (1) that the price of the asset depends on 1): individual risk parameters such as γ; 2): the rate of time preference, r, which is implied by the discount factor $\beta = 1/(1+r)$; 3): the income process; and 4): the dividend process, which is assumed to be known and common for both player types.

We assume the aggregate endowment of francs and assets is constant across periods.[7] We further suppose the dividend is equal to a constant value $d_t = \bar{d}$ for all t, so that a constant steady state equilibrium price exists.[8] The latter assumption and the application of some algebra to equation (1) yields:

$$p^* = \frac{\bar{d}}{E_t \frac{u'(c_t)}{\beta u'(c_{t+1})} - 1}. \tag{2}$$

This equation applies to each agent, so if one agent expects consumption growth or decay they all must do so in equilibrium. Since the aggregate endowment is constant, strict monotonicity of preferences implies that there can be no growth or decay in consumption for all individuals in equilibrium. Thus it must be the case that in a steady state competitive equilibrium each agent perfectly smoothes his consumption, that is, $c_t^i = c_{t+1}^i$, so equation (2) simplifies to the standard *fundamental price* equation:

$$p^* = \frac{\beta}{1-\beta}\bar{d}. \tag{3}$$

2.2 The indefinite horizon economy

Obviously we cannot observe infinite periods in a laboratory study, and the economy is too complex to elicit continuation strategies from subjects in order to compute discounted payoff streams after a finite number of periods of real-time play. As we describe in greater detail in the following section, in place of implementing an infinite horizon with constant time discounting, we follow Camerer and Weigelt (1993) and study an indefinite horizon with a constant continuation probability. This technique for implementing infinite horizon environments in a laboratory setting is quite standard in game theory experiments (e.g., Dal Bó and Fréchette 2011) and has a rich history, beginning with Roth and Murnighan (1978).

We will refer to units of the consumption good as "francs". The utility function $u(c^i)$ in the experiment thus serves as a map from subject i's end-of-period franc balance (consumption) to U.S. dollars. While shares of the asset transfer across periods, once francs for a given period are converted into dollars they *disappear from the system*, as the consumption good is not storable. Dollars accumulate across periods in a non-transferable account and are paid in cash at the end of the experiment. The indefinite horizon economy is terminated

[7]The absence of income growth in our design rules out the possibility of "rational bubbles".

[8]If the dividend is stochastic, it is straightforward to show that a steady state equilibrium price does *not* exist. Instead, the price will depend (at a minimum) upon the current realization of the dividend. See Mehra and Prescott (1985) for a derivation of equilibrium pricing in the representative agent version of this model with a finite-state Markovian dividend process. We adopt the simpler, constant dividend framework since our primary motivation was to induce an economic incentive for asset trade in a standard macrofinance setting. Porter and Smith (1995) show that implementing constant dividends in the SSW design does not substantially reduce the incidence or magnitude of asset price bubbles.

with probability $1-\beta$ at the end of each period, in which event shares of the asset become worthless. Thus, from the decision-maker's perspective, a share of the asset today is worth more than a share tomorrow not because subjects are impatient as in the infinite horizon model, but because the asset may cease to have value in the next period.

Let $m_t = u(c_t)$ and $M_t = \sum_{s=0}^{t} m_s$ denote the sum of dollars a subject has earned through period t given initial wealth m_0 (which may be zero or include some combination of the promised show-up fee, cumulative earnings during the experimental session, or even an individual's personal wealth outside of the laboratory). Superscripts indexing individual subjects are suppressed for notational convenience. Let $v(m)$ be a subject's indigenous (homegrown) utility from m dollars, and suppose this function is strictly concave, strictly monotonic, and twice differentiable. Then the subject's expected value from participating in an indefinite horizon economy is

$$V = \sum_{t=1}^{\infty} \beta^{t-1} (1-\beta) v(M_t). \tag{4}$$

The sequence $\langle s_t \rangle_{t=2}^{\infty}$ is the control used to adjust V. Maximizing (4) with respect to s_{t+1} subject to the per-period budget constraint $p_t s_{t+1} \leq p_t(s_t + d) + y_t - c_t$ yields the first-order condition for $t \geq 1$:

$$u'(c_t) p_t \sum_{s=t}^{\infty} \beta^{s-t} E_t\{v'(M_s)\} = \sum_{s=t}^{\infty} \beta^{s-t+1} E_t\{v'(M_{s+1}) u'(c_{t+1})(d + p_{t+1})\}. \tag{5}$$

Again focusing on a steady state price, the subject's first-order condition reduces to:

$$p = \frac{d}{\frac{u'(c_t)}{u'(c_{t+1})}\left(1 + \frac{v'(M_t)}{\sum_{s=t}^{\infty} \beta^{s-t+1} v'(M_{s+1})}\right) - 1}. \tag{6}$$

Notice the similarity of (6) to (2). This is not a coincidence; applying a little algebra to (6) produces (2) for linear $v(m)$. This justifies our earlier claim that the infinite horizon economy and its indefinite horizon economy analogue share the same steady-state equilibrium provided that subjects are risk neutral. We consider departures from indigenous risk neutrality later in section 5.

3 Experimental design

We seek to determine the extent to which the price and shareholding predictions of the Lucas asset pricing environment are supported within a laboratory implementation where we have good control over the environment. The expected value of holding the asset is difficult to compute relative to the SSW finite horizon setting, and no participant possesses sufficient information to calculate the equilibrium price; we assess the extent to which these values are learned through fundamentals (e.g., the dividend on the asset, the discount factor, the utility/payoff function, and the income process) and market activity. We are further interested in the important premise of consumption-based asset pricing models that agents use the asset, which in our framework is the sole store of value, to intertemporally smooth their consumption. Finally, we wish to challenge the robustness of our findings by considering the comparative static implications of changes to the parameterization of the model economy.

There are many interesting ways to vary the parameters of the model but we focus on just two binary variations, producing four treatments. First, we consider whether and how changes in the dividend process affect the price of the asset; after all, according to the theory, the present discounted sum of all future dividends is the primary determinant of the asset's price. Second, we examine whether the strength of the consumption-smoothing objective matters by varying the curvature of the agents' induced utility function over consumption. The latter treatment variation enables us to connect and differentiate our findings using the Lucas asset model with findings from multi-period asset pricing experiments of the type conducted by SSW.

Thus our experiment involves a 2×2 experimental design where the treatment variables are 1) the induced utility function, which is either strictly concave as in the Lucas model (1978, p. 1431) or linear as in SSW's approach, and 2) the dividend earned per share of the asset, which is either high or low. We conducted twenty laboratory sessions (five per treatment) of the indefinite horizon economy introduced in Section 2.2. In each session there were twelve subjects, six of each induced type, for a total of 240 subjects. The endowments of the two subject types and their utility functions in all sessions are given in Table 1.

Table 1: Induced Utility and Endowment Parameters

Type	No. Subjects	s_1^i	$\{y_t^i\} =$	$u^i(c) =$
1	6	1	110 if t is odd, 44 if t is even	$\delta^1 + \alpha^1 c^{\phi^1}$
2	6	4	24 if t is odd, 90 if t is even	$\delta^2 + \alpha^2 c^{\phi^2}$

In every session the franc endowment, y_t^i, for each type $i = 1, 2$ followed the same deterministic two-cycle. Subjects were informed that the aggregate endowment of income and shares would remain constant throughout the session, but otherwise were only privy to information regarding their own income process, shareholdings, and induced utility functions. In each session dividends took a constant value of either $\bar{d} = 2$ or $\bar{d} = 3$, and either a linear or concave utility function was induced for both subject types. Thus our four treatments were C2 (concave utility, $\bar{d} = 2$), C3 (concave utility, $\bar{d} = 3$), L2 (linear utility, $\bar{d} = 2$), and L3 (linear utility, $\bar{d} = 3$).

Utility parameters were chosen so that subjects would earn \$1 per period in the risk neutral steady state competitive equilibrium in C2 and L2. By contrast, C2 subjects earn an average of \$0.45 per period in autarky (no trade). In L2 expected earnings in autarky equaled the competitive equilibrium earnings due to the linear exchange rate. A higher dividend results in modestly higher benchmark payments; in L3 and C3 subjects earn an average of \$1.06 per period in the risk neutral steady state competitive equilibrium while the autarkic payoff in C3 averaged \$0.58 per period. This doubling of payoffs from trading versus autarky was chosen so as to make the differences sufficiently salient to subjects, in line with prior research, e.g., Gneezy and Rustichini (2000). The utility function used in each treatment was presented to subjects both as a table and as a graph converting her end-of-period franc balance to dollars.

More precisely in our baseline C2 and C3 we set $\phi^i < 1$ and $\alpha^i \phi^i > 0$.[9] Given our two-cycle income process, it is straightforward to show from (3) and the budget constraint that steady state shareholdings must also follow a two-cycle between the initial share endowment, $s^i_{odd} = s^i_1$, and

$$s^i_{even} = s^i_{odd} + \frac{y^i_{odd} - y^i_{even}}{\bar{d} + 2p^*}. \tag{7}$$

Notice that in equilibrium subjects smooth consumption by buying asset shares during high income periods and selling asset shares during low income periods. In C2 the equilibrium price is $p^* = 10$. Thus in equilibrium, according to equation (7), a type 1 subject holds 1 share in odd periods and 4 shares in even periods, and a type 2 subject holds 4 shares in odd periods and 1 share in even periods. In C3 the equilibrium price is $p^* = 15$. In equilibrium, type 1 subjects cycle between 1 and 3 shares, while type 2 subjects cycle between 4 and 2 shares.

Our primary variation on the baseline concave treatments was to set $\phi^i = 1$ for both agent types so that there was no longer an incentive to smooth consumption.[10] Our aim in the linear treatments was to examine an environment that was closer to the SSW framework. In SSW's design, the dividend process was common to all subjects and dollar payoffs were linear in francs, so risk-neutral subjects had no induced motivation to engage in trade. We hypothesized that in L2 and L3 we might observe assets trade at prices greater than the fundamental price, in line with SSW's bubble findings.

To derive the equilibrium price under linear induced utility (since the first-order conditions no longer apply), suppose there exists a steady state equilibrium price $\hat{p}$. Substituting

[9] Specifically, $\phi^1 = -1.195,\ \alpha^1 = -311.34,\ \delta^1 = 2.6074,\ \phi^2 = -1.3888,\ \alpha^2 = -327.81$, and $\delta^2 = 2.0627$.

[10] In these linear treatments, $\alpha^1 = 0.0122, \alpha^2 = 0.0161$, and $\delta 1 = \delta^2 = 0$.

each period's budget constraint we can re-write $U = \sum_{t=1}^{\infty} \beta^{t-1} u(c_t)$ as

$$U = \sum_{t=1}^{\infty} \beta^{t-1} y_t + (d + \hat{p}) s_1 + \sum_{t=2}^{\infty} \beta^{t-2} \left[\beta d - (1-\beta)\hat{p} \right] s_t. \tag{8}$$

Notice that the first two right-hand side terms in (8) are *constant*, because they consist entirely of exogenous, deterministic variables. If $\hat{p} = p^*$, the third right-hand term in (8) is equal to zero regardless of the sequence of future shareholdings, so clearly this is an equilibrium price. If $\hat{p} > p^*$, the third right-hand term is negative, so each agent would like to hold zero shares, but this cannot be an equilibrium since excess demand would be negative. If $\hat{p} < p^*$, this same term is positive, so each agent would like to buy as many shares as his no borrowing constraint would allow in each period, thus resulting in positive excess demand. Thus p^* is the unique steady state equilibrium price in the case of linear utility. We further note that in the linear case, any feasible distribution of the aggregate endowment is a supporting equilibrium allocation (since agents are indifferent to buying or selling the asset).

In all sessions of our experiment we imposed the following trading constraints on subjects:

$$y_t^i + d_t s_t^i - p_t(s_{t+1}^i - s_t^i) \geq 0,$$

$$s_t^i \geq 0,$$

where the first constraint implies no borrowing and the second implies no short sales. These constraints do not impact the fundamental price in any treatment nor do they affect steady-state equilibrium shareholdings in the concave treatments. They do restrict the set of equilibrium shareholdings in the linear treatment, which without these constraints must merely sum to the aggregate share endowment. No borrowing or short sales are standard restrictions in asset market experiments.

3.1 Induced discounting

As noted earlier, we sought to induce the stationarity associated with an infinite horizon and constant time discounting model by implementing an indefinite horizon with a stochastic number of trading periods. Each period lasted for three minutes during which time units of the asset could be bought and sold in a centralized marketplace. At the end of each period, one subject in rotation took a turn rolling a six-sided die in public view of the other participants. If the die roll in period t was between 1 and 5 inclusive, the economy continued with another period; each individual's asset position was carried over to the start of period $t+1$. If the die roll was 6, the economy abruptly came to an end and all subjects' assets were declared worthless. Thus, the probability that assets continued to have value in future trading periods was 5/6 (.833), analogous to a discount factor $\beta = 5/6$.

To give subjects the opportunity to learn from both "good" and "bad" realizations, our experimental sessions were set up so that there would likely be several such sequences of trading periods. We recruited subjects for a three-hour block of time. We informed them they would participate in one or more "sequences," each consisting of an indefinite number of "trading periods" for at least one hour after the instructions had been read and all questions answered. Following one hour of play (during which time one or more sequences were typically completed), subjects were instructed that the sequence they were currently playing would be the last one played, i.e., the next time a 6 was rolled the session would come to a close. This design ensured that we would get a reasonable number of trading periods, while at the same time limited the possibility that the session would not finish within the 3-hour time-frame for which subjects had been recruited. Indeed, we never failed to complete the final sequence within three hours.[11] The expected mean (median) number of trading periods per sequence in our design is 6 (4), respectively. The realized mean (median) were 5.2 (4) in our sessions. On average there were 3.4 sequences per session.

3.2 The trading mechanism

Another methodological issue is how to implement asset trading. General equilibrium models of asset pricing simply combine first-order conditions for portfolio choices with market clearing conditions to obtain equilibrium prices, but do not specify the actual mechanism by which prices are determined and assets are exchanged. We adopted the double auction market mechanism since it is well known to reliably converge to competitive equilibrium in a wide range of experimental markets. We used the double auction module found in Fischbacher's (2007) z-Tree software.

Specifically, prior to the start of each three-minute trading period t, each subject i was informed of her current asset position, s_t^i, and the number of francs she would have available for trade, $y_t^i + s_t^i\bar{d}$. After all subjects clicked a button indicating they understood their asset and franc positions, the trading period was begun. Subjects could post buy or sell orders for one unit of the asset at a time, though they were instructed that they could sell as many assets as they had available, or buy as many assets as they wished so long as they had sufficient francs. We instituted a standard bid-ask improvement rule: buy offers had to

[11] In the event that we did not complete the final sequence by the three hour limit, we instructed subjects at the beginning of the experiment that we would bring all of them back to the laboratory as quickly as possible to complete the final sequence. Subjects would be paid for all sequences that had ended in the current session, but would be paid for the continuation sequence only when it had been completed. Their financial stake in that final sequence would be derived from at least 25 periods of play, which makes such an event very unlikely (about 1%) but quite a compelling motivator to get subjects back to the lab. As it turned out, we did not have to bring back any group of subjects in any of the sessions we report on here, as they all finished within the 3-hour time-frame for which subjects had been recruited.

improve on (exceed) existing buy offers and sell offers had to improve on (undercut) existing sell offers to be posted in the (open) limit order book. Subjects could agree to buy or sell at a currently posted price (i.e., submit a market order) by clicking on the bid/ask, immediately after which the transaction was executed and the price publicly posted. After a trade the order book was cleared, but subjects could (and did) immediately begin reposting buy and sell orders. A history of all transaction prices in the trading period was always present on all subjects' screens, which also provided information on asset trade volume. In addition to this information, each subject's franc and asset balances were adjusted in real time in response to any transactions.

3.3 Subjects, payments and timing

Subjects were undergraduates from the University of Pittsburgh. No subject participated in more than one session of this experiment. At the beginning of each session, the 12 subjects were randomly assigned a role as either a type 1 or type 2 agent, so that there were 6 subjects of each type. Subjects remained in the same role for the duration of the session. They were seated at visually isolated computer workstations and were given written instructions that were also read aloud prior to the start of play in an effort to make the instructions public knowledge. As part of the instructions, each subject was required to complete two quizzes to test comprehension of the induced utility function, the asset market trading rules and other features of the environment; the session did not proceed until all subjects had answered these quiz questions correctly. Instructions (including quizzes, payoff tables, charts and endowment sheets) are reproduced in Appendix B.[12] Subjects were recruited for a three hour session, but a typical market ended after around two hours (which included time devoted to instructions, about 35 minutes). A remaining 15 minutes was devoted to the Holt-Laury elicitation task which was not announced in advance.

Subjects earned their payoffs from every period of every sequence played in the session. Mean (median) payoffs were \$22.65 (\$22.41) per subject in the linear sessions and \$18.75 (\$19.48) in the concave sessions, including a \$5 show-up payment but excluding the payment for the Holt-Laury individual choice experiment.[13] Payments were higher in the linear sessions because it was a zero-sum market, whereas social welfare was uniquely optimized in the steady-state equilibrium in the concave sessions.

At the end of each period t, subject i's franc balance was declared her consumption level, c_t^i, for that period; the dollar amount of this consumption holding, $u^i(c_t^i)$, accrued to her cumulative cash earnings from all prior trading periods, which were paid at the completion

[12] Copies of the instructions and materials are available at `http://www.socsci.uci.edu/~duffy/assetpricing/`.

[13] Subjects earned an average of \$7.22 for the subsequent Holt-Laury experiment and this amount was added to subjects' total from the asset pricing experiment.

of the session. The timing of events in our experimental design is summarized below:

t	dividends paid; francs=$s_t^i\bar{d}+y_t^i$, assets=s_t^i.	3-minute trading period using a double auction to trade assets and francs.	consumption takes place: $c_t^i = s_t^i\bar{d}+y_t^i$ $+\sum_{k_t^i=1}^{K_t^i} p_{t,k_t^i}\left(s^i_{t,k_t^i-1}-s^i_{t,k_t^i}\right)$.	die roll: continue to $t+1$ w.p. 5/6, else end.	$t+1$

In this timeline, K_t^i is the number of transactions completed by i in period t, p_{t,k_t^i} is the price governing the kth transaction for i in t, and s^i_{t,k_t^i} is the number of shares held by i after his kth transaction in period t. Thus $s^i_{t,0}=s^i_t$ and $s^i_{t,K_t^i}=s^i_{t+1}$. Of course, this summation does not exist if i did not transact in period t; in this "autarkic" case, $c_t^i = s_t^i\bar{d}+y_t^i$. In equilibrium, sale and purchase prices are predicted to be identical over time and across subjects, but under the double auction mechanism they can differ within and across periods and subjects.

3.4 Subject risk preferences

Following completion of the last sequence of trading periods, beginning with Session 7 we asked subjects to participate in a further brief experiment involving a single play of the Holt-Laury (2002) paired-lottery choice instrument. The Holt-Laury paired-lottery choice task is a commonly-used individual decision-making experiment for measuring individual risk attitudes. This second experimental task was not announced in advance; subjects were instructed that, if they were willing, they could participate in a second experiment that would last an additional 10-15 minutes for which they could earn an additional monetary payment from the set $\{\$0.30, \$4.80, \$6.00, \$11.55\}$.[14] All subjects agreed to participate in this second experiment. We had subjects use the same ID number in the Holt-Laury individual-decision making experiment as they used in the 12-player asset-pricing/consumption smoothing experiment enabling us to associate behavior in the latter with a measure of each individual's risk attitudes. Appendix B includes the instructions for the Holt-Laury paired-lottery choice experiment. The Java program used to carry out the Holt-Laury test may be found at `http://www.socsci.uci.edu/~duffy/assetpricing/`.

[14] These payoff amounts are 3 times those offered by Holt and Laury (2002) in their "low-payoff" treatment. We chose to scale up the possible payoffs in this way so as to make the amounts comparable to what subjects could earn over an average sequence of trading periods.

4 Experimental findings for the market experiment

We conducted twenty experimental sessions of our market experiment (a follow-up individual choice experiment will be described in section 6). Each session involved twelve subjects with no prior experience in our experimental design (240 subjects total). The treatments used in these sessions are summarized in Table 2.

Table 2: Assignment of Sessions to Treatment

Session	$\bar{d}$	$u(c)$	Holt-Laury test	Session	$\bar{d}$	$u(c)$	Holt-Laury test
1	2	concave	No	11	3	concave	Yes
2	3	concave	No	12	3	linear	Yes
3	2	linear	No	13	3	linear	Yes
4	3	linear	No	14	3	concave	Yes
5	2	linear	No	15	2	concave	Yes
6	2	concave	No	16	2	linear	Yes
7	3	linear	Yes	17	3	concave	Yes
8	3	concave	Yes	18	3	linear	Yes
9	2	concave	Yes	19	2	concave	Yes
10	2	linear	Yes	20	2	linear	Yes

We began administering the Holt-Laury paired-lottery individual decision-making experiment following completion of the asset pricing experiment in sessions 7 through 20 after it became apparent to us that indigenous risk preferences might be playing an important role in our experimental findings. Thus in 14 of our 20 sessions, we have Holt-Laury measures of individual subject's tolerance for risk (168 of our 240 subjects, or 70%).

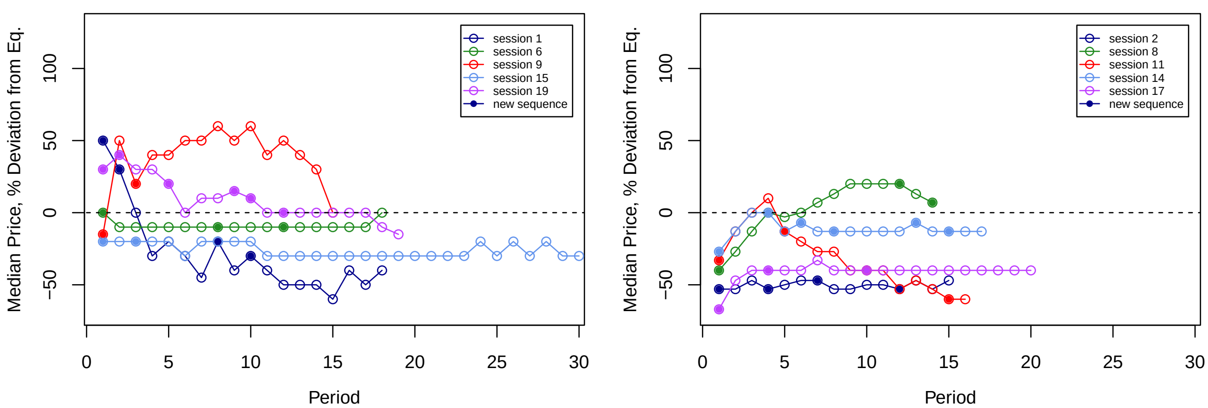
On average about 23 shares were traded in each period of the sessions of this experiment. Trading volume was a bit more than one share per period higher in the concave than linear sessions, and about 1.5 shares per period higher in high dividend than low dividend sessions. Mean (median) allocative efficiency – earnings as a fraction of the payoffs that were possible under the competitive equilibrium prediction – averaged 0.73 (0.80) for the concave economies with no difference by dividend, while the linear economies were fully efficient by construction. We summarize our main results as a number of different findings, beginning with the concave utility treatments.

4.1 Findings for induced concave utility

Finding 1 *In the concave utility treatment ($\phi^i < 1$), observed transaction prices at the end of the session were less than or equal to p^* in 9 of 10 sessions.*

Figure 1 displays median transaction prices by period for the concave sessions, $\bar{d} = 2$ is on the left and $\bar{d} = 3$ is on the right. Solid dots represent the first period of a new indefinite trading sequence. To facilitate comparisons across sessions, prices have been transformed into percentage deviations from the predicted equilibrium price (e.g., a price of -40% in panel (a), where $\bar{d} = 2$, reflects a price of 6, whereas a price of -40% in panel (b), where $\bar{d} = 3$, reflects a price of 9).

Figure 1: Equilibrium-normalized Prices, Concave Sessions



(a) Concave $\bar{d} = 2$

(b) Concave $\bar{d} = 3$

Of the ten concave utility sessions depicted in panels (a) and (b), half end relatively close to the asset's fundamental price (their deviations from the fundamental price range between -15% and 7%) while the other half finish well below it (deviations between -30% and -60%). Several sessions did experience upward pressure on prices above the fundamental price (most notably sessions 8 and 9), but these "bubbles" were self-correcting by the end of the session, and in general prices trended down in the concave sessions, especially in the second half of the sessions (we'll provide more formal evidence of this statement in the discussion of Finding 3). We emphasize that these corrections were wholly endogenous rather than forced by a known finite horizon as in SSW. We further emphasize that while prices in the concave treatment lie at or below the prediction of $p^* = \frac{\beta}{(1-\beta)}\bar{d}$, subjects were never informed of this fundamental trading price (as *is* done in some of the SSW-type asset market experiments). Indeed in our design, p^* must be inferred from fundamentals alone, namely β and $\bar{d}$ and a presumption that agents are forward-looking, risk-neutral expected utility maximizers.

We next address a main implication of consumption-based asset pricing models, that subjects use the asset to intertemporally smooth consumption. We report that:

Finding 2 *In the concave utility treatments, there is strong evidence that subjects used the asset to intertemporally smooth their consumption.*

Figure 2 shows the per capita shareholdings of type 1 subjects by period (the per capita shareholdings of type 2 subjects is five minus this number). Dashed vertical lines denote the final period of a sequence,[15] dashed horizontal lines mark equilibrium shareholdings (the bottom line in odd periods of a sequence, the top line in even periods). Recall that equilibrium shareholdings follow a perfect two-cycle, increasing in high income periods and decreasing in low income periods. As Figure 2 indicates, a two-cycle pattern (in sign) is precisely what occurred in each and every period on a per capita basis.[16]

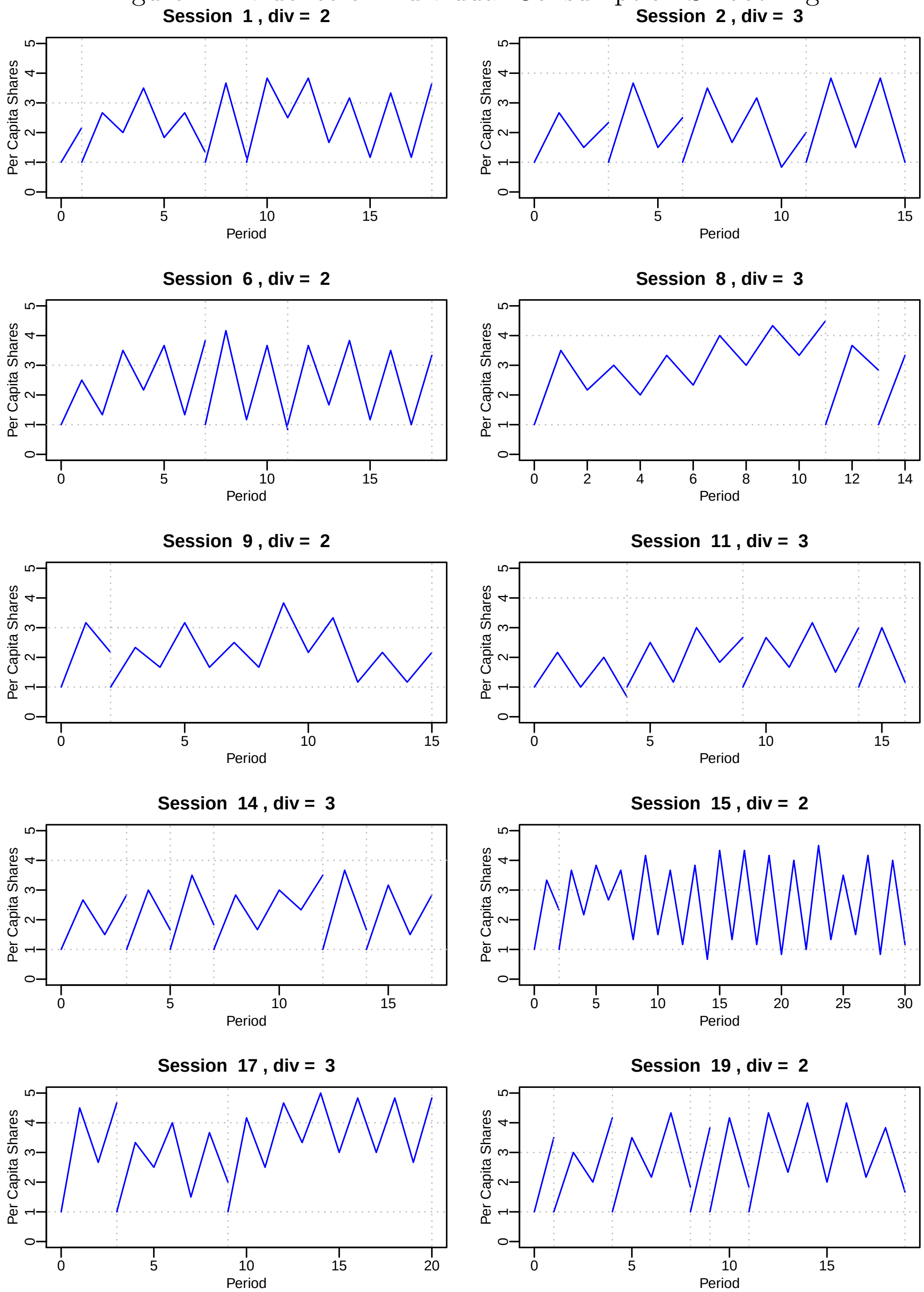
Pooling across all concave sessions, type 1 subjects (on net) bought an average of 1.94 shares in odd periods (when they had high endowments of francs) and sold an average of 1.75 shares in even periods (when they had low endowments of francs). By contrast, in the linear sessions, type 1 subjects bought an average of only 0.53 shares in odd periods and sold an average of 0.25 shares in even periods. Thus, while there was a modest degree of consumption-smoothing that took place in the linear sessions (on a per capita basis, type 1 subjects bought shares in odd periods in all ten sessions on average, and sold shares in even periods in seven of ten sessions on average), the much greater change in mean share position by type in the concave sessions (nearly four times as large) indicates that it was the concavity of induced utility that mattered most for the consumption-smoothing observed in Figure 2, and not the cyclic income process alone.

We can also confirm a strong degree of consumption-smoothing across individuals. Consider the proportion of periods a subject smoothes consumption; that is, the proportion of periods that a type 1 (2) subject buys (sells) shares if the period is odd, and sells (buys) shares if the period is even. Figure 3 displays the cumulative distribution across subjects of this proportion, pooled by whether the session had linear or concave induced utility functions. Half of the subjects in the concave sessions smoothed consumption in more than 80% of all trading periods while less than 2% of subjects in the linear sessions smoothed consumption so frequently. Well over 90% of the subjects in the concave sessions smoothed consumption in at least half of the periods, whereas only 35% of the subjects in the linear sessions smoothed consumption that frequently. The difference between these distributions

[15] Thus there are two allocations associated with each vertical line except the final one: the final shareholdings of the sequence, and the re-initialized asset endowment of the following sequence (always one unit).

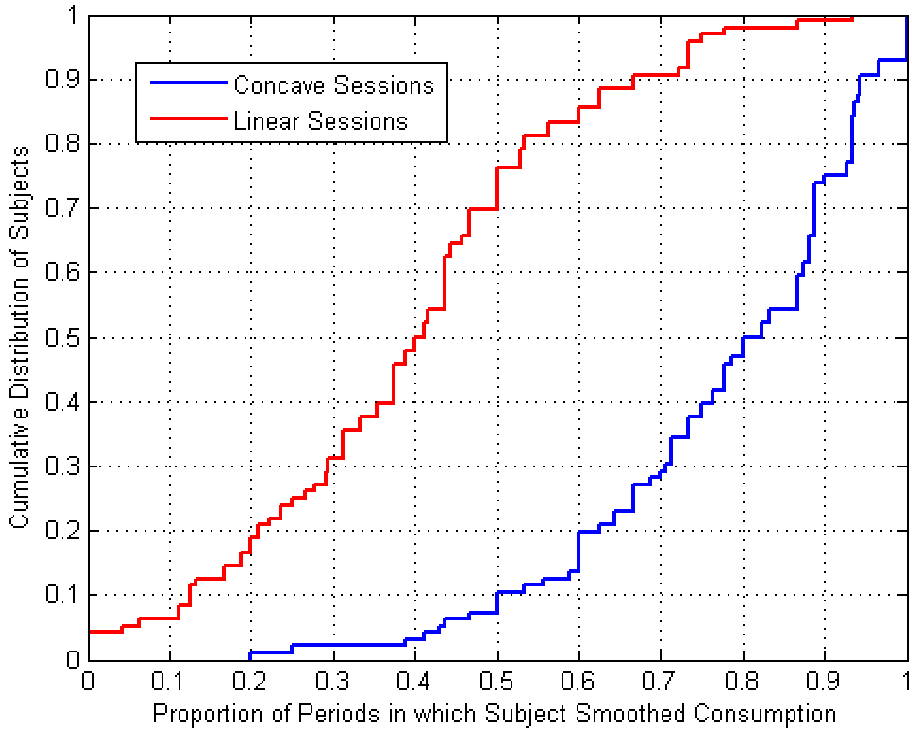
[16] In these graphs, the period numbers shown are aggregated over all sequences played. From a subject's perspective, each sequence started with period 1.

Figure 2: Evidence of Individual Consumption-Smoothing



is significant to many digits using a Wilcoxon rank-sum test. We note that the comparative absence of consumption smoothing in the linear sessions is not indicative of anti-consumption smoothing behavior. Rather, it results from the fact that many subjects in the linear treatment did not actively trade shares in many periods. It is clear from the figure that subjects

Figure 3: Evidence of Individual Consumption-Smoothing



in the concave sessions were actively trading in most periods, and had a strong tendency to smooth their consumption.

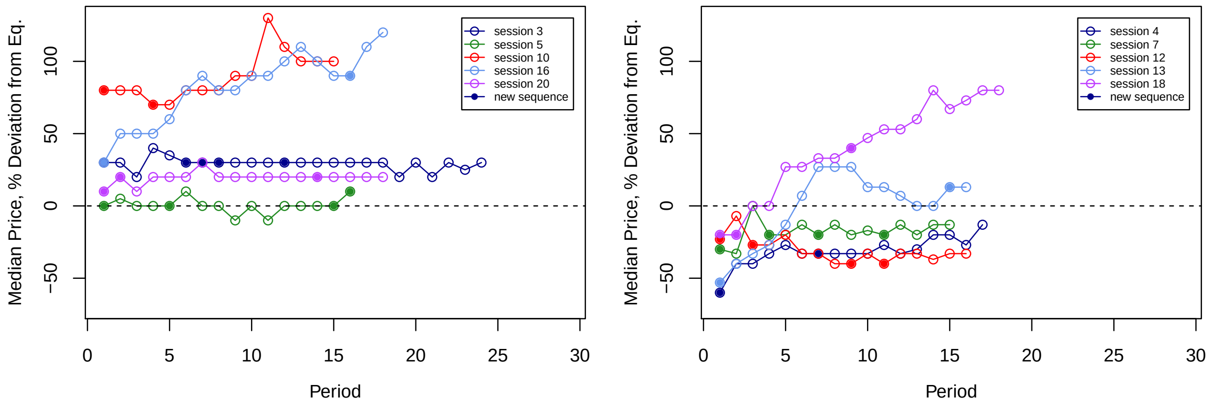
As noted in the introduction, the experimental evidence on whether subjects can learn to smooth consumption in an optimal manner (without tradeable assets) has not been encouraging; by contrast, in our design where subjects must engage in trade in the asset in order to implement the optimal consumption plan and can observe transaction prices, consumption-smoothing seems to come rather naturally to most subjects.

4.2 Findings for induced linear utility

Finding 3 *In the linear induced utility sessions ($\phi^i = 1$) trade in the asset did occur, at volumes similar to those observed in the concave sessions. Normalized transaction prices in the linear utility sessions are significantly higher than prices in the concave utility sessions.*

Figure 4 displays median transaction prices by period for the linear sessions, $\bar{d} = 2$ is on the left and $\bar{d} = 3$ is on the right. As with Figure 1, solid dots represent the first period of a new indefinite trading sequence and prices have been transformed into percentage deviations from the predicted equilibrium price.

Figure 4: Equilibrium-normalized Prices, Linear Sessions



(a) Linear $\bar{d} = 2$

(b) Linear $\bar{d} = 3$

Table 3 displays the median transaction price over several frequencies at the individual session level, and an average of these median prices at the treatment level. Notice that for a given dividend value $\bar{d}$, the average treatment price at each frequency is higher in the linear case than the corresponding concave case. Further, the price difference between linear and concave treatments involving the same $\bar{d}$ value is generally diverging over time; in moving from the median price over all periods, to the median second-half price, to the median price in the final five periods, to the median price in the final period, the average treatment price is monotonically *decreasing* in the concave treatments and monotonically *increasing* in the linear treatments. To see evidence of these trends at the session level we calculate the Mann-Kendall τ statistic, a non-parametric measure of monotonic trend, for each session. The support of the τ statistic is in the $[-1, 1]$ interval, where $\tau = -1$ indicates a strictly monotonic negative trend, $\tau = 1$ indicates a strictly monotonic positive trend, and $\tau = 0$ indicates no trend. The τ values and significance levels are reported in the last two columns of Table 3. We observe that five of the ten linear sessions have a significantly positive trend while only one has a signifcantly negative trend ($p < .05$) while four of ten concave sessions have a significantly negative trend while only one has a significantly positive trend (again, $p < .05$). Thus nearly half of the twenty sessions are diverging in prices from each other by induced utility, while only 10% are changing in the opposite direction.

This evidence suggests that price differences between the concave and linear sessions would likely have been even greater if our experimental sessions had involved more periods of play. For this reason, we choose to look for treatment differences in median prices during the final period of each session. Another justification for our focus on final period prices is that in a relatively complicated market experiment such as this one there is the potential for significant learning over time; prices in the final period of each session reflect the actions

Table 3: Median Transaction Prices By Session and Treatment

	Median	First Pd	Final Half	Final 5 Pds	Final Pd	τ	p-value
C2-Mean	**9.6**	**10.9**	**9.4**	**9.0**	**8.3**		
S1	7	15	6	5	6	-0.67	0.0002
S6	9	10	9	9	10	0	1
S9	14	8.5	15	14	10	0.02	0.9592
S15	7	8	7	7	7	-0.39	0.0132
S19	11	13	10	10	8.5	-0.80	$<$ 0.0001
L2-Mean	**14.2**	**13.0**	**15.0**	**15.0**	**15.6**		
S3	13	13	13	13	13	-0.32	0.0609
S5	10	10	10	10	11	-0.06	0.8248
S10	18	18	20	20	20	0.63	0.0027
S16	18	13	20	20	22	0.81	$<$ 0.0001
S20	12	11	12	12	12	0.27	0.1946
C3-Mean	**10.8**	**8.4**	**10.8**	**10.6**	**10.4**		
S2	7	7	7	7	8	0.15	0.5174
S8	15	9	17	17	16	0.70	0.0010
S11	10	10	8	7	6	-0.78	$<$ 0.0001
S14	13	11	13	13	13	-0.13	0.5698
S17	9	5	9	9	9	0.28	0.1551
L3-Mean	**13.8**	**9.4**	**15.0**	**15.4**	**16.0**		
S4	10	6	11	12	13	0.72	0.0002
S7	13	10.5	13	13	13	0.33	0.1282
S12	10	11.5	10	10	10	-0.46	0.0228
S13	16	7	17	16	17	0.41	0.0356
S18	20	12	24	26	27	0.95	$<$ 0.0001

of subjects who are the most experienced with the trading institution, realizations of the continuation probability, and the behavior of other subjects. Final period prices thus best reflect learning and long-term trends in these markets.

In comparing treatments for fixed dividends, the difference in the distribution of final period prices is significantly different between L2 and C2 (Wilcoxon two-tailed p-value is 0.019) but not between L3 and C3 (p-value is 0.139). Average differences are quite large in both cases. Pooling across dividends by induced utility, we observe that the median price in the final period of the linear sessions was 32% above the fundamental price on average, while in the concave sessions this average median price was 24% below the fundamental price. The associated Wilcoxon p-value is 0.011, rejecting the null hypothesis that equilibrium-normalized final period prices in the pooled linear sessions were drawn from the same distribution as the concave sessions. We justify pooling the dividend conditions based on the fact that the distributions of final period prices in C2 vs. C3 and L2 vs. L3 are not statistically significant at the 5% level (p-values of 0.172 and 0.094, respectively).

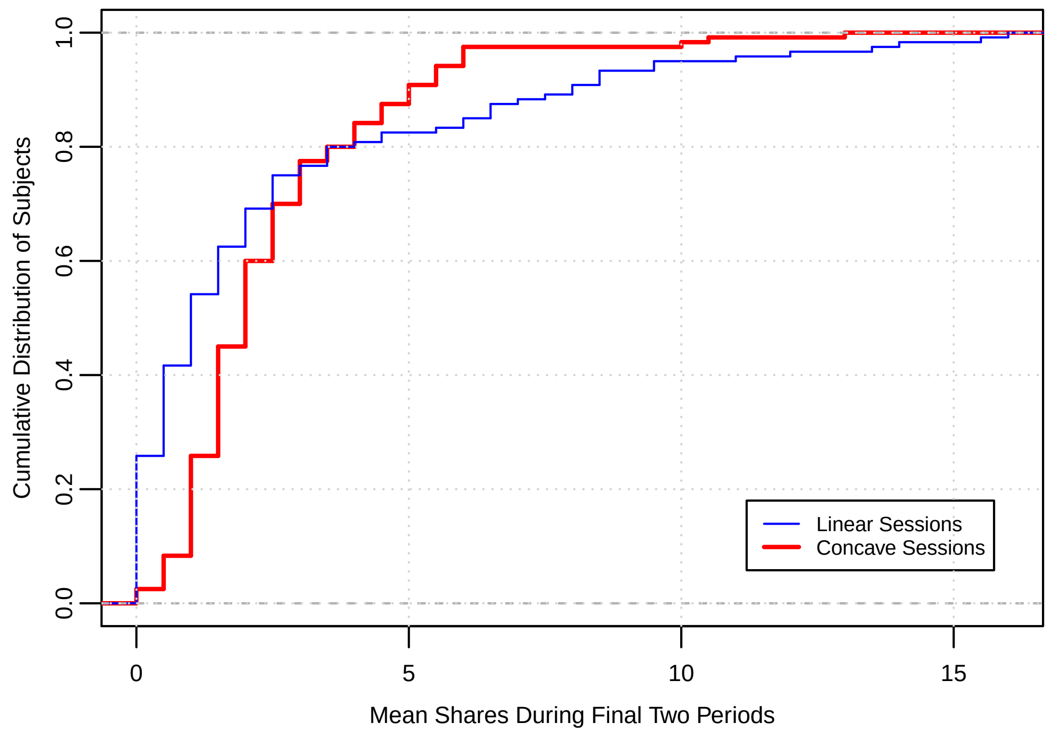
Thus the evidence is strong that the difference in induced preferences caused a strong impact on prices by the end of the session; prices were considerably greater than the fundamental value in the linear sessions, and considerably below the fundamental value in the concave sessions. We are presented with a puzzle regarding where prices initialized in the sessions. From Figures 1 and 4 it is clear that relative to the fundamental price, all C3 sessions initialized at a first-period price below the first-period price in all sessions in C2, and all L3 sessions initialized at a first-period price below the first-period price in all sessions of L2. This difference could be a consequence of the tighter budget constraint for higher dividends, or it could simply take some time for subjects to develop an appreciation for the relationship between dividend and asset value. More puzzling, we also observe that on average, *non-normalized* prices were also higher for $\bar{d} = 2$ than $\bar{d} = 3$ (pooling sessions by dividend, we reject the null hypothesis that the median first-period prices in the $\bar{d} = 2$ sessions come from the same distribution as the prices in the $\bar{d} = 3$ sessions; the associated two-tailed Wilcoxon rank-sum p-value is 0.049). Thus dividend had an unexpectedly negative (though relatively small) impact on prices in the first period, while the induced utility condition in the first period had no impact (pooled p-value of 0.240). However, by the end of the session, average non-normalized prices were higher for $\bar{d} = 3$ than $\bar{d} = 2$ within each induced utility condition (though not statistically significant); thus by the end of the experiment induced utility was the main driver of price differences.

Finding 4 *In the linear utility treatment, the asset was "hoarded" by just a few subjects.*

In the linear treatment subjects had no induced motivation to smooth consumption, and thus no induced reason to trade at p^* under the assumption of risk neutrality. However, we nevertheless observe substantial trade in these linear sessions, with close to half of the subjects selling nearly all of their shares, and a small number of subjects accumulating most of the shares. Figure 5 displays the cumulative distribution of mean individual shareholdings during the final two periods of the final sequence of each session, aggregated according to whether the treatment induced a linear or concave utility function.[17] We average across the final two periods due to the consumption-smoothing identified in Finding 3; use of final period data would bias upward the shareholdings of subjects in the concave sessions. We

[17]We use the final sequence with a duration of at least two periods.

Figure 5: Distribution (by Treatment) of Mean Shareholdings During the Final Two Periods



consider the final two periods rather than averaging shares over the final sequence or over the entire session because it can take several periods within a sequence for a subject to achieve a targeted position due to the budget constraint. Forty-two percent of subjects in the linear sessions held an average of 0.5 shares or less during the final two periods. By contrast, just 8% of subjects in the concave sessions held so few shares during the final two periods. At the other extreme, 17% of subjects in the linear sessions held an average of at least 6 shares during the final two periods, while only 6% of subjects in the concave sessions held so many shares. Thus subjects in the linear sessions were six times more likely to hold 'few' (< 1) shares and three times more likely to hold 'many' (≥ 6) shares as were subjects in the concave sessions, while subjects in the concave sessions were more than twice as likely to hold an intermediate quantity (between 1 and 6) of shares (86% vs. 41%).

A useful summary statistic for the distribution of shares is the Gini coefficient, a measure of inequality that is equal to zero when each subject holds an identical quantity of shares and is equal to one when one subject owns all shares. Under autarky, where subjects hold their initial endowments (type 1 subjects hold 1 share, type 2 subjects hold 4 shares), the Gini coefficient is 0.3. In the consumption-smoothing equilibrium of the concave utility treatment, the Gini coefficient when $\bar{d} = 2$ (treatment C2) is the same as under autarky: 0.3. When $\bar{d} = 3$ (treatment C3), the Gini coefficient (over two periods) is slightly lower at 0.25. We find that the mean Gini coefficient for mean shareholdings in the final two periods of all concave sessions is 0.37. By contrast, the mean Gini coefficient for mean shareholdings in the final two periods of all linear sessions is significantly larger, at 0.64; (the Wilcoxon p-value is significant to many significant digits). This difference largely reflects the "hoarding" of a large number of shares by just a few subjects in the linear treatment, behavior that was absent in the concave treatment sessions.[18]

We next turn to the impact of innate risk preferences on behavior in our experiment, in an attempt to predict who is holding these shares.

After running the first six sessions of our experiment it became apparent to us that the "indigenous" (home-grown) risk preferences of subjects might be a substantial influence on asset prices and the distribution of shareholdings, particularly in the linear sessions. Thus beginning with our seventh experimental session we asked subjects to participate in a second experiment involving the Holt and Laury (2002) paired lottery choice instrument. This second experiment occurred *after* the asset market experiment had concluded and was *not* announced in advance to minimize any influence on decisions in the asset market experiment. In this second experiment subjects faced a series of ten choices between two lotteries, A and B, each paying either a low or high payoff. Lottery A had a low variance between payoffs while lottery B had a high variance.[19] For choice $n \in \{1, 2, ..10\}$, the probability of getting the high payoff in the chosen lottery was $(0.1)n$. For each subject one of the ten choices was selected at random. Then the corresponding lottery was played (with computer-generated probabilities) and the subject paid according to the outcome. As detailed in Holt and Laury, a risk-neutral expected utility maximizer should choose the high-variance lottery B six times. We refer to a subject's *HL score* as the number of times the subject selected the high variance lottery, B. HL scores lower than 6 indicate risk aversion with regard to uncertain monetary payoffs while scores greater than 6 indicate risk-seeking preferences; a score of 6 is consistent with risk neutral preferences. The mean HL score from our sessions was 3.869, with a standard deviation of 1.81, indicating moderate overall risk aversion. Roughly 17% of our subjects had an HL score of at least 6, and 30% had a score of at least 5, indicating a fairly

[18]Indeed, an interesting regularity is that exactly two of twelve subjects in each of the ten linear sessions held an average of at least 6 shares of the asset during the final two trading periods (recall the aggregate endowment in all sessions is 30 shares). Thus the subjects identified in the right tail of the distribution in Figure 5 were divided up evenly across the ten linear sessions. The actual proportion of shares held by the two largest shareholders during the final two periods averaged 63% across all linear sessions, compared with just 39% across all concave sessions. The distribution of shares held by the largest two shareholders in the linear sessions is significantly larger than the distribution found in the concave sessions (Wilcoxon p-value is significant to many digits.

[19]The high and low payments for lottery A were \$6 and \$4.80, respectively, and those for lottery B were \$11.55 and \$0.30. These were the payments used in the baseline Holt and Laury treatment but scaled up by a multiple of 3, so that the stakes in our paired-choice lottery were similar to expected equilibrium payments for a sequence of our market experiment.

typical distribution of choices for lotteries of this scale.

Pooling dividends and comparing linear versus concave induced utility, we conducted an OLS regression of average subject shareholdings during the final two periods of the session on the subject's HL score for that session. In the linear case, the estimated coefficient on the HL score variable was 0.54 and its associated p-value was 0.006 (the full regression results are presented in Table A-1 of Appendix A). Thus the regression predicts that a 1 standard deviation increase in the Holt Laury score (equal to 1.9 additional high-variance choices) results in a subject holding about 1 additional share of the asset by the end of the period. This is a large impact, as there are only 2.5 shares per capita in these economies.[20] On the other hand, in the concave case the estimated OLS coefficient on the HL score is -0.159 with an associated p-value of 0.191 (full results are reported in Table A-3 of Appendix A). Thus we find that the HL score is a useful predictor of final shareholdings only in the linear sessions: The more risk-tolerant a subject (as measured by her HL score), the more shares she tended to own by the end of a linear session. We summarize this finding as follows:

Finding 5 *More risk tolerant subjects (as identified through the Holt-Laury paired lottery choice task) held significantly more shares of the asset in the linear, but not in the concave treatment sessions.*

As noted above, we conducted the Holt-Laury test *after* the market experiment had concluded as the latter was the main focus of our study. However, this order of tasks could have affected outcomes in the Holt-Laury risk elicitation. To check whether this was the case, we regressed individual subjects' HL scores on dummy variables for the two treatment conditions, 'linear' and '$D3$' and on the individual subjects' earnings from the first, asset market part of our experiment. The OLS regression results, with robust standard errors clustered on session-level observations as reported in Table A-4 of Appendix A, indicate that neither of the two treatment variables or subjects' earnings are statistically significant factors in explaining HL scores across sessions. This is reassuring evidence that the HL scores that we elicited following the asset pricing part of our experiment were not affected by asset market conditions or payoff outcomes.

[20]Since the distribution of HL scores within-session is endogenous, the OLS specification will produce biased errors. As a robustness check, we also regressed each subject's share of the total HL score within-session (summed across subjects) on his average final shareholdings. The coefficient on the HL score is 33.6 with an associated p-value of 0.002 (full regression results reported in Table A-2 of Appendix A). Playing against the observed frequency of HL scores in all of our sessions, a risk-neutral subject with a score of 6 is predicted to hold 0.54 shares more than a subject with an HL score of 5, the same prediction as is found using the raw score approach. Other 1-score predicted differences ranged from 0.47 to 0.62 shares.

5 Impact of indigenous risk aversion on behavior

The HL scores in our experiment suggest that most subjects (83%) are risk averse, in contrast with our simplifying assumption of expected value maximization.[21] In this section we focus on optimal risk-averse behavior in our market experiment, and we also consider risk-neutral behavior under non-fundamental prices. We maintain the assumption of constant prices for tractability. We leverage this assumption in a follow-up individual choice experiment, reported in Section 6, which can be viewed as a dynamic risk elicitation task.

Our focus begins with Equation 6, where up to this point we have assumed that intrinsic utility, $v(\cdot)$, is linear. To explore the impact of concave v we must first attend to the definition of initial wealth, m_0, which is implicit in Equation 6 (recall that $M_t = \sum_{s=0}^{t} m_s$, where m_s is (marginal) income in period s and m_0 is initial wealth). The conventional economics perspective is that m_0 corresponds to the (unobserved) wealth of individual subjects at the start of the experiment; individuals are assumed to care only about the utility of consumption levels, and lab earnings are integrated with pre-experiment wealth prior to subsequent consumption decisions. However, as Rabin (2000) argues, it is difficult to rationalize the preponderance of risk aversion in small-stakes experiments given the likely distribution of wealth levels with which subjects enter the lab. That is, the amount of money available in the lab can barely nudge the post-experiment consumption of participants, so if utility function curvature impacts choices under such relatively small stakes, then choices in comparatively more substantial circumstances should exhibit implausibly large degrees of risk aversion.

Thus for risk aversion to play a role in laboratory decision-making, subjects must compartmentalize utility within the timeframe of the laboratory experiment. But even here we face several possibilities. Do subjects maximize a lab utility function? A horizon utility function (re-initializing m_0 at the start of each new horizon)? A period utility function (re-initializing m_0 at the start of each new period)? By restricting focus to concave v over lab choices we necessarily assume substantial myopia, but the question remains, how much myopia is reasonable? Our subsequent analysis maintains flexibility in this regard.

5.1 Optimal behavior in the linear market treatment

We begin with the market experiment in which induced utility is linear (treatments L2 and L3), so that $u(c) = \alpha c$. From Equation 6, prices can be constant only if $v'(M_{t+1}) = kv'(M_t)$

[21] We measured a total of 240 subject HL scores between the market and individual choice experiments (the latter are reported in Section 6). Of these scores, 83% were in the risk-averse range of 1 to 5 high-variance choices, 11% were risk neutral, and 6% were in the risk-seeking range of 7 to 10 high-variance choices.

for all t, in which case Equation 6 reduces to:

$$k = \frac{\bar{d}}{\left(p + \bar{d}\right)\beta}. \tag{9}$$

For $p \geq p^*$ we necessarily have $k \geq 1$. That is, subjects prefer marginal utility to grow rather than decay over time, which is infeasible for concave v, and thus the corner solution is optimal. Therefore for prices greater than or equal to the fundamental price, indigenously risk averse subjects should immediately sell all shares of the asset in the first period and not trade for the remainder of the horizon. This prediction for indigenously risk averse agents holds for all degrees of within-session myopia; that is, behavior is the same regardless of whether the subject fixes her initial wealth m_0 at the beginning of the experiment, or at the start of each new horizon, or at the start of each period. By contrast, an indigenously risk-neutral subject should buy as many shares as permitted by her budget constraint when $p < p^*$, sell all her shares when $p > p^*$, and is unrestricted in her behavior when $p = p^*$. And a risk-seeking subject should buy as many shares as permitted by her budget constraint when $p \leq p^*$.

This characterization provides strong restrictions for competitive market behavior in our experiment, provided subject HL scores are consistent with indigenous utility v. If all subjects in a session have a HL score less than 6, we should observe $p < p^*$ in all periods. If one subject has an HL score equal to 6 and the rest less than 6, we should observe $p \leq p^*$ in all periods. If one subject has an HL score greater than 6 and the rest have scores less than 6, there are no sign restrictions on price. If at least two subjects have HL scores equal to 6 and there are no scores greater than 6, we should observe $p = p^*$ (or one price tick below p^*) in all periods. If at least one subject has an HL score equal to 6 and only one subject has an HL score greater than 6, we should observe $p \geq p^*$ in all periods. And if there are at least two subjects with HL scores greater than 6, we should observe $p > p^*$ in all periods.

We observe seven induced linear markets for which have HL scores, and in six of those markets we have a price restriction characterized above (in the seventh we observe one risk-seeking subject while the rest are risk averse). Focusing on terminal prices to allow the full extent of learning to take place, our linear market sessions are consistent with these price restrictions in only 1 of 6 sessions. Further, recall that 7 of our 10 linear market sessions ended with prices greater than p^*. Since 94% of our subjects have HL scores no greater than 6, but only 25% of subjects held zero shares during the final two periods of the linear market sessions, it also appears that most individual level behavior in the induced linear markets cannot be explained by concave v.

To test this hypothesis more rigorously, in Section 6 we detail a follow-up experiment in which subjects made decisions in an individual choice setting: All were endowed with Type 1 induced utility, endowments and income, and given the opportunity to trade at a constant price of either p^* or $p > p^*$. This experiment can be interpreted as a dynamic risk elicitation task without the complication of price/liquidity uncertainty; myopic, indigenously risk-averse subjects should immediately sell all of their shares at these prices, though we confirm that most subjects do not behave in this manner.

5.2 Optimal behavior in the concave market treatment

For the parameterization used in the experiment, when induced utility is concave we can re-write Equation 6 as

$$\left(\frac{c_t}{c_{t+1}}\right)^{\phi-1}\left[1+\frac{v'(M_t)}{\sum_{s=t}^{\infty}\beta^{s-t+1}v'(M_{s+1})}\right]=\frac{p+d}{p}, \tag{10}$$

where ϕ is a treatment parameter that was set to be -1.195 for Type 1 subjects and -1.3888 for Type 2 subjects.

Consider first the optimal behavior of an indigenously risk-neutral subject in this induced concave utility treatment. In this case Equation 10 reduces to

$$c_{t+1}=\left[\frac{p}{\beta(p+d)}\right]^{\phi-1}c_t, \tag{11}$$

since when v is linear, we have that $z \equiv 1+\frac{v'(M_t)}{\sum_{s=t}^{\infty}\beta^{s-t+1}v'(M_{s+1})}=\frac{1}{\beta}$. Thus, for an indigenously risk-neutral subject, optimal consumption follows a constant growth rate when $p < p^*$, a constant rate of decay when $p > p^*$, and is constant when $p = p^*$. The range of this optimal consumption growth/decay for prices observed in our induced concave market experiments is relatively small. Recall that, on average, prices ended 24% below the fundamental price in these sessions, and consider a price 30% below fundamental (this will be a fixed price reported in our individual choice experiment in Section 6). At such a low price, a risk-neutral subject would be expected to grow consumption at a rate of 3.2% per period within each horizon.

For an indigenously risk-averse subject with concave v, it must be the case that $z > 1/\beta$ because his marginal utility of wealth is strictly decreasing; the only way $z = 1/\beta$ for concave v is if $M_s = M_t$ for all $s > t$; that is, all expected earnings in the experiment accrue in current period t. The absence of borrowing makes such an expected earnings stream infeasible in our experiment.

Thus since $z > 1/\beta$ for all concave v, it follows that $\left(\frac{c_t}{c_{t+1}}\right)^{\phi-1}$ must be *smaller* for a risk-averse subject relative to a risk-neutral subject in any period t. This observation implies that, relative to an indigenously risk-neutral subject, an indigenously risk-averse subject will optimally choose a slower consumption growth rate in any period than his risk-neutral counterpart. This growth (or decay) rate is not constant and asymptotically approaches the risk-neutral rate in the limit as t goes to infinity for a subject who maximizes a session utility function. In the extreme myopic case where wealth is reinitialized to 0 in each period, the subject's planned consumption path is time-inconsistent (that is, in each period the subject plans a consumption path where wealth effects disappear in the limit, but re-sets this path in each period). Thus the extremely myopic subject's deviation from risk neutrality does not disappear over time.

Now consider a typical distribution of HL scores in an induced concave session, with a maximum HL score less than 7,[22] and suppose $p = p^*$. Subjects with HL scores of 6 should smooth consumption perfectly, whereas subjects with HL scores less than 6 (that is, most subjects) should front-load consumption but move toward perfect consumption smoothing during the session. Thus we should expect to see prices start below p^* in the induced concave sessions, but move toward p^* within the session. We do indeed generally observe prices below the fundamental price in the induced concave market sessions. However, the departures from the fundamental price can be substantial, and our market prices tend to trend downward and away from p^* rather than towards it.

In addition to a comparative static comparison of behavior for concave vs. linear v, we can also say something about the magnitude of predicted differences in behavior. Equation 10 predicts modest consumption growth for risk-neutral subjects when $p < p^*$, and even smaller growth (or even, initially, decay) for risk-averse subjects. For example, predicted consumption growth of 3.2% for a risk-neutral subject when the price is 30% below the fundamental price amounts to a difference of less than 3 francs for a Type 1 subject between periods 1 and 2 (to benchmark this difference, maximal consumption-smoothing at this price would entail consuming 84 and 82 francs in periods 1 and 2, respectively), while this difference would be even smaller for a risk-averse subject. Thus even relatively large deviations from the fundamental price predict relatively small differences in behavior.

Further complicating the analysis, share choices in our experiment were discrete rather than continuous; the predicted difference in behavior in a continuous economy is substantially smaller than the size of the grid. For these reasons, Equation 10 does not present us with testable predicted differences in individual behavior, unlike the strong predicted differences under linear induced utility. All subjects should make choices relatively close to perfect consumption smoothing for the range of prices observed in our experiment. In other words, the induced concavity of the utility function in our experiment should substantially dominate any curvature in subjects' home-grown, indigenous preferences.

As partial confirmation of the extent to which induced concave utility constrains optimal behavior, consider the fact that only 7% of subjects in the induced concave market exper-

[22] In 4 of 7 concave sessions there are no subjects with HL scores greater than 6, and in the other 3 sessions there is one subject in each with an HL score greater than 6.

iment earned more than the equilibrium benchmark, and these subjects were all within 7 cents per period of equilibrium earnings. But the median subject earned only 20% less than the equilibrium benchmark. In our follow-up individual choice experiment, under induced concave utility 22% of subjects earned more than the equilibrium benchmark, but all these subjects remained within 7 cents per period of equilibrium earnings. The median subject earned only 7% less than the equilibrium benchmark.

Finally, consider subjects who adopts a simple behavioral strategy of the optimal 2-cycle of shares, discounting the second period of the cycle at rate β. That is, a subject who buys x shares in high-income periods and sells x shares in low income periods, and chooses x to maximize induced $u(odd) + \beta u(even)$. Consider placing such subjects within an induced concave $\bar{d} = 2$ market experiment. Interestingly, every price between 1 and 20 is a behavioral equilibrium for such subjects, provided there are an equal number of both agent types. For $p < 9$, subjects trade 4 shares of the asset per period, for prices between 9 and 12 (inclusive) subjects trade 3 shares of the asset, for prices between 13 and 20 (inclusive) subjects trade 2 shares of the asset. What's more, the per-period average utility of this behavioral equilibrium is at least 96 cents per subject for all prices between 5 and 20 (exclusive); compared to the (fundamental) equilibrium payment of \$1 per subject, there is virtually no loss for either subject at any price (total efficiency is within 1 cent of fundamental efficiency in all of these behavioral equilibria). Therefore induced concave utility in our design makes it impossible to earn substantially more money than maximal consumption-smoothing permits, and maximal consumption-smoothing constitutes a behavioral equilibrium strategy.

6 Eliminating Price and Liquidity Uncertainty

In our experiment there are two main sources of uncertainty. One is uncertainty about the planning horizon, and the other is uncertainty associated with trading (i.e., future prices and liquidity). In this section we report on an additional set of experimental sessions in which we eliminated price and trade uncertainty by allowing subjects to buy and sell the asset at an exogenously fixed market price.[23] In this case one can interpret the asset as a storage technology with a known fixed rate of return. The aim of these additional sessions was to understand how *individual* subjects behaved in response to market prices that were either at, below, or above fundamental value, in a setting where there is no uncertainty about the future stream of possible transaction prices. We can also interpret these individual choice sessions as a dynamic risk elicitation task that matches our market experiment framework as closely as possible while leveraging the constant price assumption used to develop the characterization of behavior under small-stakes risk-aversion as set forth in Section 5.

[23] We thank an anonymous referee for suggesting such a treatment.

Session	$\bar{d}$	$u(c)$	Prices (No. Subjects)	
17	2	Concave	7 (6)	10 (6)
18	2	Concave	7 (6)	10 (6)
19	2	Concave	7 (6)	10 (6)
17-19	2	Concave	7 (18)	10 (18)
20	2	Linear	10 (6)	13 (6)
21	2	Linear	10 (6)	13 (6)
22	2	Linear	10 (6)	13 (6)
20-22	2	Linear	10 (18)	13 (18)

Table 4: Individual choice sessions

The model parameterization of β and $u(c)$ in these new sessions were the same as in the original market experiment, with all subjects assigned Type 1 endowments and the corresponding high-low income process.[24] Each subject traded to maximize his own payoff objective with no spillover effects onto other subjects and with trade restricted only by his budget constraint. We set the dividend $\bar{d} = 2$ so that the fundamental price of the asset in all sessions was $p^* = 10$.

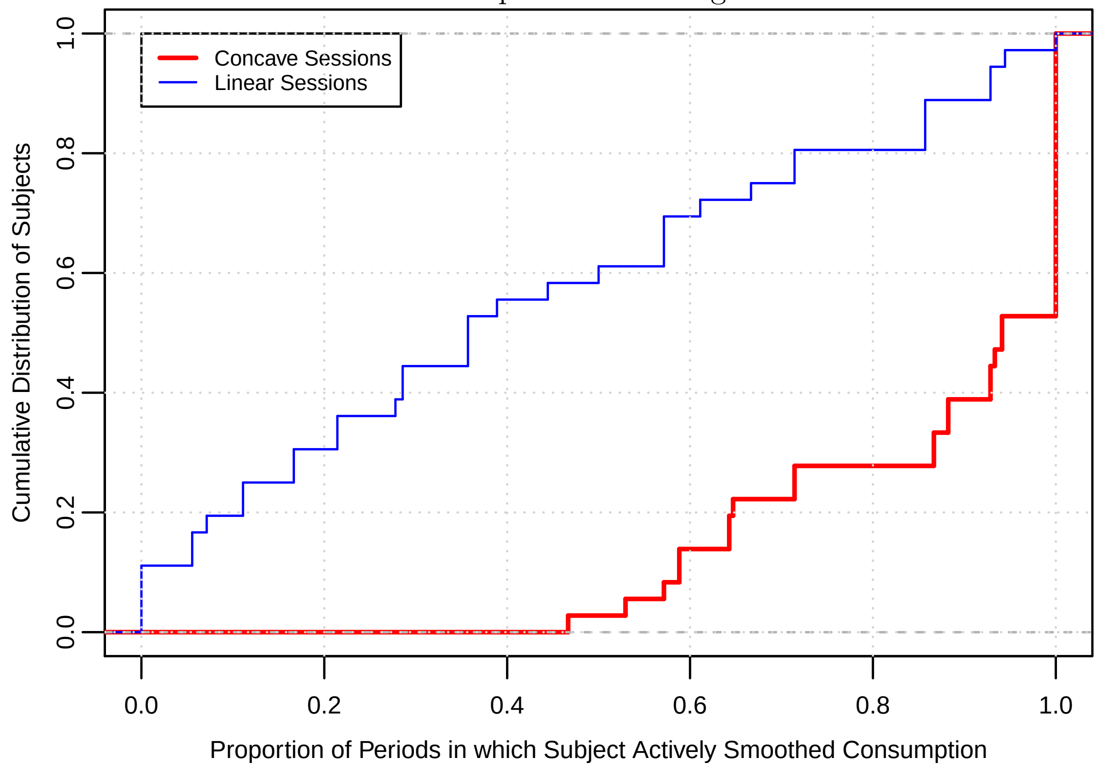
Our first treatment variable in these new sessions was the induced utility function, linear or concave, and our second treatment variable was the fixed price at which subjects could buy or sell the asset, $p \in \{7, 10, 13\}$, subject to the same budget constraint as in the market experiment. Our aim in the $p \neq p^*$ treatments was to better comprehend subject behavior under non-fundamental prices that approximated those often found in our asset market experiment (recall in our concave market sessions that prices averaged 24% below p^* and in the linear sessions they averaged 32% above p^*). The price and induced utility faced by a given subject did not change throughout a session.

The trading interface was simple: Subjects entered a desired quantity of shares in a text box and chose whether to "Buy" or "Sell" that number of shares. Subjects who wished to maintain their share position in the current period were instructed to enter "0" in the text entry box and click either "Buy" or "Sell." Thus, the effort to hold was equal to the effort to buy or sell shares.

Table 4 summarizes the treatments we conducted of this individual choice experiment, which involved six new experimental sessions with 12 subjects per session (72 subjects in total). As Table 4 reveals we have 18 independent observations each of: (1) C2 with a fixed price of 10 (C2-10), (2) C2 with a fixed price of 7, (C2-7), (3) L2 with a fixed price

[24] As prices were exogenous, there was no need to have two player types to induce a motivation for trade in the asset.

Figure 6: Evidence of Individual Consumption-Smoothing In Individual Choice Treatments



of 10 (L2-10) and (4) L2 with a fixed price of 13 (L2-13). The subjects in these individual choice sessions were also University of Pittsburgh undergraduates who had not previously participated in any of our market experiments. At the end of these individual choice sessions, subjects were again asked to complete a Holt-Laury risk preference elicitation. The instructions used in these individual choice experiments are reproduced in Appendix B.

Our first result characterizes consumption-smoothing in the individual choice treatments. Consider first the proportion of periods in which each subject bought shares in high-income periods and sold shares in low-income periods. There is no significant difference in these distributions between C2-10 and C2-7 (Wilcoxon p-value 0.80) or between L2-10 and L2-13 (p-value 0.14). However, the difference is significant (to many significant digits) between the pooled linear and concave treatments. The empirical CDFs of this trading activity are shown in Figure 6. Notice that nearly half of the subjects in the concave treatments smoothed their consumption in every period.

Comparing these distributions with the market treatment counterparts (in Figure 3), there is no statistically significant difference in consumption smoothing between the linear individual choice and the linear market treatments (p-value 0.88), but there is a significant difference between the concave individual choice and concave market treatments (p-value 0.001). Subjects in the concave individual choice treatments smooth their consumption to an even greater extent than do subjects in the comparable concave market treatments, which we attribute to the simpler individual choice environment involving no price uncertainty.

Consider next the standard deviation of end-of-period franc consumption for each subject, proportional to the same standard deviation in autarky. The means of these ratios (across subjects) are 1.58 and 1.33 in L2-10 and L2-13, respectively, and 0.52 and 0.57 in C2-10 and C2-7, respectively. These ratios are not significantly different between L2-10 and L2-13 (Wilcoxon p-value of 0.28) or between C2-10 and C2-7 (p-value of 0.84). Pooling subjects into linear and concave treatments, these normalized standard deviations are significantly different from autarky in both cases to many significant digits. In fact, only 3 of 36 subjects had a standard deviation of consumption greater than autarky in the concave treatments, while only 5 of 36 subjects had a standard deviation of consumption less than autarky in the linear treatments. This result provides strong additional evidence for consumption-smoothing at the individual level in the concave treatments. Further, we note that the typical consumption variance in the linear treatments is even greater than the autarkic cycle of 112 francs in odd periods and 46 francs in even periods. Thus, while the sign of trading decisions is consistent with consumption smoothing in the linear treatments at least half of the time for nearly 40% of subjects (as revealed in Figure 6), these subjects are not actually consumption-smoothing at all. We summarize these results as follows.

Finding 6 *The extent of consumption smoothing is significantly greater in the concave individual choice setting than in the concave market setting, which we attribute to the price certainty of the individual choice setting. Eliminating price uncertainty has no effect on the extent of consumption smoothing in the linear utility setting, where it continues to be far less than in the concave treatment.*

We next characterize trading volume. In C2-10, 96% of choices were (weakly) on the sell side in low-income periods and 87% involved sales between 0-3 units. In high-income periods, 93% of the choices were (weakly) on the buy side, and 75% involved purchases between 0-3 units. Thus most trades took place within the relatively narrow range of selling 0-3 shares in even periods, and buying 0-3 shares in odd periods. The mean decision was to sell 2 shares in even (low-income) periods and buy 2.5 shares in odd (high-income) periods.

In C2-7, 95% of choices in low-income periods were (weakly) on the sell side, but only 58% involved sales between 0-3 units. In high-income periods, 98% of choices were (weakly) on the buy side, but only 50% involved purchases between 0-3 units. Expanding the trading band to ± 5 shares captures 81% (83%) of decisions in even (odd) periods, respectively. The mean decision in even periods was to sell 2.7 shares, and the mean decision in odd periods was to buy 3.4 shares. Thus, while the overwhelming tendency in both concave treatments was to sell shares in even periods and buy shares in odd periods, the volume of trade was substantially larger when the price was 7 rather than 10 (in both odd and even periods, the distribution of choices in C2-10 vs. C2-7 are significantly different from each other, with Wilcoxon p-values less than 0.01). Maximal consumption smoothing required buying/selling 3 shares in high/low-income periods of treatment C2-10 and 4 shares in treatment C2-7, so mean trading volume was within one share of maximal consumption smoothing in both treatments.

Finding 7 *Trading volume was significantly larger under a price of 7 rather than 10 in the concave treatments, just enough to keep the mean extent of consumption smoothing between treatments roughly constant.*

In the linear treatments we also find a significant impact of price on trading volume. In L2-10 only 77% of trades in low-income periods and 63% of trades in high-income periods were within ± 5 shares; thus nearly one-third of all trades involved more than 5 shares of the asset in a given period. However, this wide range of activity shrank substantially in L2-13, where 92% of trade activity in low-income periods (83% in high-income periods) occurred in the ± 3 range.

However, despite this intuitive price effect, few subjects actually "cash out" as predicted by the expected utility characterization developed in Section 5. In L2-10, where 16 of 18 subjects are in the risk-averse range of HL scores, no subject held zero shares throughout the session. Only 3 of these "risk-averse" subjects held no shares of the asset during the final two periods of the session, and one of these three actually held an average of more than 11 shares per period throughout the session. If we adopt "near cash out" criteria of (1) Holding fewer than one share on average in the final two periods, (2) Ending at least one-third of all periods with zero shares, and (3) Holding less than two shares per period on average throughout the session, then only 1 of 16 subjects with HL scores less than 6 is even close to completely cashing out in L2-10. The one subject in this treatment with an HL score in the risk-seeking range did hold many shares in the session (4.9 shares on average, finishing with 7.5 shares on average in the final two periods), but not nearly so high as would be predicted by optimal risk-seeking behavior.

In L2-13, 17 of 18 subjects have an HL score less than or equal to 6, and thus are predicted to cash out entirely in all periods of the session. In fact, 2 of these 17 subjects do exactly that. Two other subjects meet the "near cash out" criteria specified above. Therefore, the characterization of behavior presented for induced linear preferences in Section 5 provides binding restrictions for 34 of 36 subjects (provided HL score is an accurate measure of risk preferences). Only 2 of these 34 subjects (6%) satisfy this characterization strictly, and a total of 6 (18%) satisfy the characterization at least approximately. Thus few subjects appear to act consistently as within-session expected utility maximizers in these induced linear individual choice sessions.

Finding 8 *In the linear treatments, trading volume was substantially reduced under a price of 13 relative to a price of 10. However, the behavior of very few subjects (18%) was even approximately consistent with within-session expected utility theory.*

Finally we examine whether there is any relationship between shareholdings and our Holt-Laury risk measure. That is, even though the HL score fails to give us accurate point predictions of behavior, it may potentially explain differences between subjects. We focus on mean shareholdings for each subject during the final two periods of a session to facilitate comparison with the market treatments. Recall that in the pooled linear market experiment, 42% of subjects held less than one share during the final two periods, while 16% held at least 6 shares; these proportions were 8% and 6%, respectively, in the concave market sessions. The data from the individual choice treatments bracket the market data by price. In L2-13 (L2-10), 44% (17%) of subjects held less than one share during the final two periods, while 11% (28%) held six or more. Thus, at the high price (13), subjects in the linear, individual choice experiment were much more likely to cash out and much less likely to hold a large number of shares. In C2-7 (C2-10), 11% (0%) of subjects held an average of less than one share during the final two periods, while 11% (6%) held an average of at least six shares, both relatively similar to what was observed in the market experiment.

The correlation of HL scores with final shareholdings is quite interesting. Consistent with the market experiment, there is not a significant relationship between HL score and final shareholdings in either of the concave individual choice treatments using OLS. Also consistent with the market experiment, there is a statistically significant and positive impact of HL score on final shareholdings when price equals 10 in the linear individual choice treatment (the coefficient on HL score is large, 0.93, with an associated p-value of 0.0337; full results reported in Table A-5 in Appendix A). However, there is not a statistically significant relationship between HL score and final shareholdings in the linear individual choice treatment when $p = 13$; in fact, the estimated coefficient is negative (-0.192, p-value 0.784; see Table A-6 in Appendix Z). This was unexpected, suggesting a re-investigation of the market experiment data.

We first partition our linear *market* treatment sessions into two groups: Those sessions where the average price in the final two periods was at least 30% greater than the fundamental value, and those with a lower price.[25] For the low-price group, there is not a statistically

[25] This partition has several useful properties: (1) Thirty percent represents the fixed, high-price designation in the individual choice experiment; (2) Thirty percent separates the market treatment sessions into two relatively equal-sized groups; and (3) There is a distinct difference in prices between the two groups (the low-price group has prices of -33%, -13%, 13%, and 20% relative to fundamental, while the high-price group has prices of 80%, 100% and 115% of fundamental). Similar results obtain if we define the high price group as being 20% or more above fundamental price.

		Final Shareholdings by HL Score		
Treatment	**Price**	**HL 1-4**	**HL 5-7**	**HL 8-10**
Market	Low	2.19	3.01	3.83
Market	High	1.13	5.13	2.5
Choice	Low	3.14	5.13	NaN
Choice	High	2.07	2.17	NaN

Table 5: Mean Final Shares in Linear Individual Choice Sessions

significant relationship between HL score and final shareholdings (coefficient 0.39, p-value 0.1131), while for the high-price group there is a significantly positive relationship (the coefficient is 0.81, p-value 0.0142). Adjusting for HL score heterogeneity between sessions by regressing a subject's share of the total HL score within-session on final shareholdings corroborates this result.[26] See Tables A-7 and A-8 in Appendix A for regression details.

Thus, HL scores are predictive of shareholdings for low but not high prices in the linear individual choice sessions, and for high but not low prices in the linear individual choice treatment sessions. We develop some insight into what drives this difference by considering how shareholdings change from low to high prices when we bin HL scores into three groups: Those within one score of risk neutral (6 ± 1) and those with scores above or below that "risk-neutral bin". Table 5 displays average final shareholdings in each of these bins (note that only 4 of 84 subjects in the linear market sessions and 0 of 36 subjects in the linear individual choice sessions have an HL score greater than 7, so we cannot make formal inferences about this group alone). What seems apparent is that subjects generally purchase fewer shares under high prices **except** approximately risk-neutral subjects in a market setting, who tend to purchase considerably more shares. While there is no significant difference between the distribution of shareholdings for approximately risk-neutral subjects versus other subjects when prices are low (Wilcoxon p-value 0.9901) in the market sessions, there is a significant difference when prices are high (p-value 0.0022).

Finding 9 *The distribution of final shareholdings in the individual choice sessions appears to be relatively consistent with shareholdings in the market sessions for both concave and linear induced utility. However, while most subjects hold fewer shares in the linear individual choice sessions when the price is high, in the linear market sessions, subjects who are approximately risk-neutral according to the Holt-Laury elicitation substantially increase their shareholdings.*

[26]The slope coefficient is 21 with a p-value of 0.124 in the low-price case, while the coefficient is 53 with a p-value of 0.0026 in the high-price case

Thus at prices 30% above fundamental in the linear individual choice experiment, most subjects (understandably) reduce their purchases. However, in the linear *market* experiment, such high prices cause a particular group of subjects to increase their demand for shares; namely, those identified as being approximately risk-neutral according to the Holt-Laury task. The question, of course, is: Why? Here we must become speculative and leverage the existing literature to hazard a plausible explanation.

We begin with De Martino, O'Doherty, Ray, Bossaerts and Camerer (2013), who report an increased propensity to "ride" financial bubbles in a SSW setting for individuals whose economic value computations (in the ventromedial prefrontal cortex) are affected by social signals (computed in the dorsomedial prefrontal cortex). Their interpretation is that individuals who incorporate inferences about the intentions of others when making financial valuation decisions are the most likely to bid asset prices above fundamentals, fueling a bubble. "These results suggest that during financial bubbles, participants' choices are less driven by explicit information available in the market (i.e., prices and fundamentals) and are more driven by other computational processes, perhaps imagining the path of future prices and likely the behavior of other traders." (p. 1223) That is, individuals with a strong theory of mind (ToM) suffer "enhanced susceptibility to buying assets at prices exceeding their fundamental value." (p. 1223)

Ibanez, Huepe, Gempp, Gutiérrez, Rivera-Rei, and Toledo (2013) establish a strong relationship between fluid intelligence and ToM, while Benjamin, Brown and Shapiro (2013) establish a relationship between cognitive ability and small-stakes risk neutrality. Assuming that the associated correlations aggregate so that small-stakes risk neutrality is associated with higher ToM, these papers suggest that we could see approximately risk-neutral subjects bidding up asset prices in our linear market experiment but demanding less shares at high prices in our linear individual choice experiment, because in the linear choice experiment there are no intentions of "others" for these subjects to predict.

7 Conclusion

Our aim in this paper was to demonstrate how one could implement and test some of the comparative static predictions of consumption-based asset pricing models in the controlled conditions of the laboratory. As we noted in the introduction, the laboratory allows for more careful control over the environment and data measurement than is possible using field data, and we think that laboratory experiments should at least complement analyses of asset pricing behavior using field data. An additional aim was to build a bridge between the experimental asset pricing literature which has typically followed the SSW experimental design and the equilibrium asset pricing models used by macroeconomic/business cycle and finance researchers which are mainly consumption-based. To date there has been little communication between researchers in these two literatures.

In our concave market treatments, which implement a version of Lucas's (1978) consumption-based asset pricing model, we found that the theory generally performs well. Prices of the asset lie at or below the equilibrium predicted level and increase with increases in the dividend, that is, they respond to changes in economic fundamentals. Most significantly, there is strong evidence that, consistent with the theory, subjects are using the asset to intertemporally smooth their consumption by buying the asset in periods in which they have high incomes and selling the asset in periods in which they have low income.

In our linear market treatments which are closer to the SSW design in the sense that there is no motive for subjects to use the asset to smooth consumption or to engage in any trade in the asset whatsoever, we find that asset prices are considerably higher than in the comparable concave treatment sessions. If we loosely define a bubble as a sustained deviation of asset prices above the fundamental price, more than one-half of our linear treatment economies experienced bubbles, and in five of those six sessions the bubble exhibited no signs of collapse. Indeed, in three of these sessions the median price of the asset towards the end of the experiment was more than double the fundamental price and was continuing to rise. By contrast, when consumption-smoothing was induced in an otherwise identical economy as in our concave treatments, prices bubbled in only three of 10 sessions, and in all three of these sessions the median price of the asset had collapsed to the fundamental price by the (random) end of the experimental session. Thus, price bubbles were less frequent, of lower magnitude, and of shorter duration when we induced a consumption-smoothing motive in an otherwise identical economy. In fact, prices were nearly 25% below the fundamental price on average in the concave treatment sessions; subjects could hold the asset at a premium (in expected value) relative to its sale price.

When we eliminated price and liquidity uncertainty in our individual choice experiments, we found even stronger evidence that subjects used the asset to intertemporally smooth consumption in our concave treatment, but no evidence for such consumption smoothing in our linear treatment.

Our experimental design can be extended in at least three distinct directions. First, the design can be moved a step closer to the environments used in the macrofinance literature; specifically, by adding a Markov process for dividends and/or a known, constant growth rate in endowment income. The purpose of such treatments would be to explore the robustness of our present findings in the deterministic setting to stochastic or growing environments. A further step would be to induce consumption-smoothing through overlapping generations rather than via a cyclic income process and a concave exchange rate.

In another direction, it would be useful to clarify the impact of features of our experimental design relative to the much-studied experimental design of Smith, Suchanek, and Williams (1988). For example, one could study a finite horizon, linear (induced) utility design as in SSW, but where there exists a constant probability of firm bankruptcy as in our present design. Would the interaction of a finite horizon but the possibility of firm bankruptcy inhibit bubbles relative to the SSW design, or is an induced economic incentive to trade assets necessary to prevent a small group of speculators from effectively setting asset prices across a broad range of economies?

Finally, it would be useful to design an experiment to better understand what "small-stakes risk aversion" entails in the context of a dynamic asset pricing experiment. Assuming that subjects maximize a within-lab expected utility function is a natural place to start, but the wealth effects implied by that assumption do not generally appear in the data, neither in our experiment nor in others. Given the (inverse) relationship between small-stakes risk aversion and cognitive ability, it would seem a more heuristic approach might prove useful. More theoretical development is required, particularly theory that incorporates scale as a feature of the model.

We leave these extensions and additional experimental designs to future research.

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Appendix A: Regression Results

Table A-1: OLS Regression of Final Shares on HL Scores, Linear

$s_i = \beta_0 + \beta_1 h_i + \varepsilon_i$

s_i = average shares of subject i during the final 2 periods of the (linear) session

h_i = HL score of subject i in the (linear) session

	Coefficient	Standard Error	z	$P > \|z\|$
β_1	0.5435	0.1912	2.842	0.00565
β_0	0.2612	.8669	0.301	0.76398

Residual standard error: 3.317 on 82 degrees of freedom

Multiple R-squared: 0.08967, Adjusted R-squared: 0.07857

F-statistic: 8.078 on 1 and 82 DF, p-value: 0.005653

Table A-2: OLS Regression of Final Shares on HL Score Shares, Linear

$s_i = \beta_0 + \beta_1 h_i + \varepsilon_i$

s_i = average shares of subject i during the final 2 periods of the (linear) session

h_i = HL score of subject i divided by the sum of HL scores within the session

	Coefficient	Standard Error	z	$P > \|z\|$
β_1	33.5725	10.5291	3.189	0.00203
β_0	-0.2977	0.9476	-0.314	0.75418

Residual standard error: 3.279 on 82 degrees of freedom

Multiple R-squared: 0.1103, Adjusted R-squared: 0.09946

F-statistic: 10.17 on 1 and 82 DF, p-value: 0.002025

Table A-3: OLS Regression of Final Shares on HL Scores, Concave

$s_i = \beta_0 + \beta_1 h_i + \varepsilon_i$

s_i = average shares of subject i during the final 2 periods of the (concave) session

h_i = HL score of subject i in the (concave) session

	Coefficient	Standard Error	z	$P > \|z\|$
β_1	-0.1590	0.1224	-1.300	0.197
β_0	3.0755	0.4880	6.302	1.39e-08

Residual standard error: 1.879 on 82 degrees of freedom

Multiple R-squared: 0.02018, Adjusted R-squared: 0.008232

F-statistic: 1.689 on 1 and 82 DF, p-value: 0.1974

Table A-4: Linear Regression of HL Score on Treatment Dummies and Earnings

$h_i = \beta_0 + \beta_1 Linear + \beta_2 D3 + \beta_3 \pi_i + \epsilon_i$

h_i = subject i's Holt Laury score

Linear: linear treatment dummy

D3: $d = 3$ treatment dummy

π_i = subject i's earnings

OLS Regression	Number of obs = 168
R^2: 0.0196	F(3,13) = 0.85
Root MSE =1.8085	Prob > F=0.4929

h_i	Coef.	Std. Error	t	$P > \|t\|$	[95% Confidence Interval]
β_1	0.48265	0.34910	1.38	0.190	[-0.2715289, 1.236823]
β_2	-0.02579	0.32133	-0.08	0.937	[-0.7199748, 0.668395]
β_3	0.00606	0.02670	0.23	0.824	[-0.0516208, 0.0637456]
β_0	3.54818	0.42785	8.29	0.000	[2.623864, 4.472488]

Table A-5: OLS Regression of Final Shares on HL Scores, L10 Choice

$s_i = \beta_0 + \beta_1 h_i + \varepsilon_i$

s_i = average shares of subject i during the final 2 periods of the session

h_i = HL score of subject i in the session

	Coefficient	Standard Error	z	$P > \|z\|$	
β_1	0.9306	0.4006	2.323	0.0337	
β_0	0.1713	1.5745	0.109	0.9147	

Residual standard error: 2.404 on 16 degrees of freedom

Multiple R-squared: 0.2522, Adjusted R-squared: 0.2054

F-statistic: 5.395 on 1 and 16 DF, p-value: 0.0337

Table A-6: OLS Regression of Final Shares on HL Scores, L13 Choice

$s_i = \beta_0 + \beta_1 h_i + \varepsilon_i$

s_i = average shares of subject i during the final 2 periods of the session

h_i = HL score of subject i in the session

	Coefficient	Standard Error	z	$P > \|z\|$	
β_1	-0.1923	0.6911	-0.278	0.784	
β_0	2.8526	2.8863	0.988	0.338	

Residual standard error: 3.524 on 16 degrees of freedom

Multiple R-squared: 0.004817, Adjusted R-squared: -0.05738

F-statistic: 0.07744 on 1 and 16 DF, p-value: 0.7844

Table A-7: OLS Reg. of Final Shares on HL Scores, Linear Market Low Price

$s_i = \beta_0 + \beta_1 h_i + \varepsilon_i$

s_i = average shares of subject i during the final 2 periods of the session

h_i = HL score of subject i in the session

	Coefficient	Standard Error	z	$P > \|z\|$
β_1	0.3942	0.2440	1.615	0.113
β_0	0.8987	1.1053	0.813	0.420

Residual standard error: 3.388 on 46 degrees of freedom

Multiple R-squared: 0.05369, Adjusted R-squared: 0.03311

F-statistic: 2.61 on 1 and 46 DF, p-value: 0.1131

Table A-8: OLS Reg. of Final Shares on HL Scores, Linear Market Low Price

$s_i = \beta_0 + \beta_1 h_i + \varepsilon_i$

s_i = average shares of subject i during the final 2 periods of the session

h_i = HL score of subject i in the session

	Coefficient	Standard Error	z	$P > \|z\|$
β_1	0.8129	0.3145	2.585	0.0142
β_0	-0.9097	1.4266	-0.638	0.5280

Residual standard error: 3.262 on 34 degrees of freedom

Multiple R-squared: 0.1643, Adjusted R-squared: 0.1397

F-statistic: 6.683 on 1 and 34 DF, p-value: 0.0142

Appendix B: Instructions Used in the Experiment (for online publication)

The instructions distributed to subjects in the C2 market treatment are reproduced on the following pages. Subjects in the C3 treatment received identical instructions, except that dividends were changed from 2 to 3 throughout. Subjects in the L2 and L3 treatments received identical instructions to their counterparts in C2 and C3, respectively, except for the fourth paragraph. The modified fourth paragraph in the instructions for the L2 and L3 treatments is reproduced at the end of the C2 treatment instructions.

Following these instructions we present a reproduction of the endowment sheets, payoff tables, and payoff charts for all subjects.

After these supplements we present the instructions distributed to all subjects for the Holt-Laury paired-choice lottery.

Finally, we present instructions from the individual choice, C2-10 treatment. The other individual choice treatment sessions are similar except that the prices that subjects could buy or sell at was either 7, 10 or 13 and the payoff function was linear in the L2 treatments.

A complete set of all instructions used in all treatments of this experiment can be found at `http://www.socsci.uci.edu/~duffy/assetpricing/`

Market Treatment Instructions

I. Overview

This is an experiment in the economics of decision making. If you follow the instructions carefully and make good decisions you may earn a considerable amount of money that will be paid to you in cash at the end of this session. Please do not talk with others for the duration of the experiment. If you have a question please raise your hand and one of the experimenters will answer your question in private.

Today you will participate in one or more "sequences", each consisting of a number of "trading periods". There are two objects of interest in this experiment, francs and assets. At the start of each period you will receive the number of francs as indicated on the page entitled "Endowment Sheet". In addition, you will earn **2** francs for each unit of the asset you hold at the start of a period (please look at the endowment sheet now). During the period you may buy assets from or sell assets to other participants using francs. Details about how this is done are discussed below in section IV.

At the end of each period, your end-of-period franc balance will be converted into dollar earnings. These dollar earnings will accumulate across periods and sequences, and will be paid to you in cash at the end of the experiment. The number of assets you own carry over from one period to the next, if there is a next period (more on this below), whereas your end-of-period franc balance does not -you start each new period with the endowment of francs indicated on your Endowment Sheet. Therefore, there are two reasons to hold assets: (1) they provide additional francs at the beginning of each period and (2) assets may be sold for francs in some future period.

Please open your folder and look at the "Payoff Table" showing how your end-of-period franc balance converts into dollars. The "Payoff Chart" provides a graphical illustration of the payoff table. There are several things to notice. First, very low numbers of francs yield negative dollar payoffs. The lowest number in the payoff table is **11** francs. You are not permitted to hold less than **11** francs at any time during the experiment. Second, the more francs you earn in a period, the higher will be your dollar earnings for that period. Finally, the dollar payoff from each additional franc that you earn in a period is diminishing; for example, the payoff difference between 56 and 57 francs is larger than the difference between 93 and 94 francs.

*NOTE: The **total** number of francs and assets held by all participants in this market does not change over the course of a sequence. Further, the number of francs provided by each asset, **2**, is the same for all participants.*

II. Preliminary Quiz

Using your endowment sheet and payoff table, we now pause and ask you to answer the following questions. We will come around to verify that your answers are correct.

1. Suppose it is the first period of a sequence (an odd-numbered period). What is the number of assets you own? _______________

2. What is the total number of francs you have available at the start of the first period, including both your endowment of francs and the 2 francs you get for each unit of the asset you own at the start of the period? _______________

3. Suppose that at the end of the first period you have not bought or sold any assets, so your franc total is the same as at the start of the period (your answer to question 2). What is your payoff in dollars for this first period? _______________

4. Suppose that the sequence continues with period 2 (an even-numbered period), and that you did not buy or sell any assets in the first period, so you own the same number of assets. What is the total number of francs you have available at the start of period 2, including both your endowment of francs and the 2 francs you get for each unit of the asset you own at the start of a period? _______________

5. Suppose again that at the end of period 2 you have not bought or sold any assets, so your franc total is the same as at the start of the period (your answer to question 4). What is your payoff in dollars for this second period? _______________ What would be your dollar earnings in the sequence to this point? _______________

III: Sequences of Trading Periods

As mentioned, today's session consists of one or more "sequences," with each sequence consisting of a number of "periods." Each period lasts 3 minutes. At the end of each period your end-of-period franc balance, dollar payoff and the number of assets will be shown to you on your computer screen. One of the participants will then roll a die (with sides numbered from 1-6). If the number rolled is 1-5, the sequence will continue with a new, 3-minute period. If a 6 is rolled, the sequence will end and your cash balance for that sequence will be final. Any assets you own will become worthless. Thus, at the start of each period, there is a 1 in 6 (or about 16.7 percent) chance that the period will be the last one played in the sequence and a 5 in 6 (or about 83.3 percent) chance that the sequence will continue with another period.

If less than 60 minutes have passed since the start of the first sequence, a new sequence will begin. You will start the new sequence and every new sequence just as you started the first sequence, with the number of francs and assets as indicated on your endowment sheet. The quantity of francs you receive in each period will alternate as before, between odd and even periods, and the total number of assets available for sale (across all participants) will remain constant in every period of the sequence. If more than 60 minutes has elapsed since the beginning of the first sequence then the current sequence will be the last sequence played; that is, the next time a 6 is rolled the sequence will end and the experiment will be over. The total dollar amount you earned from all sequences will be calculated and you will be paid this amount together with your $5 show-up fee in cash and in private before exiting the room.

If, by chance, the final sequence has not ended by the three-hour period for which you have been recruited, we will schedule a continuation of this sequence for another time in which everyone here can attend. You would be immediately paid your earnings from all sequences that ended in today's session. You would start the continuation sequence with the same number of assets you ended with in today's session, and your franc balance would continue to alternate between odd and even periods as before. You would be paid your earnings for this final sequence after it has been completed.

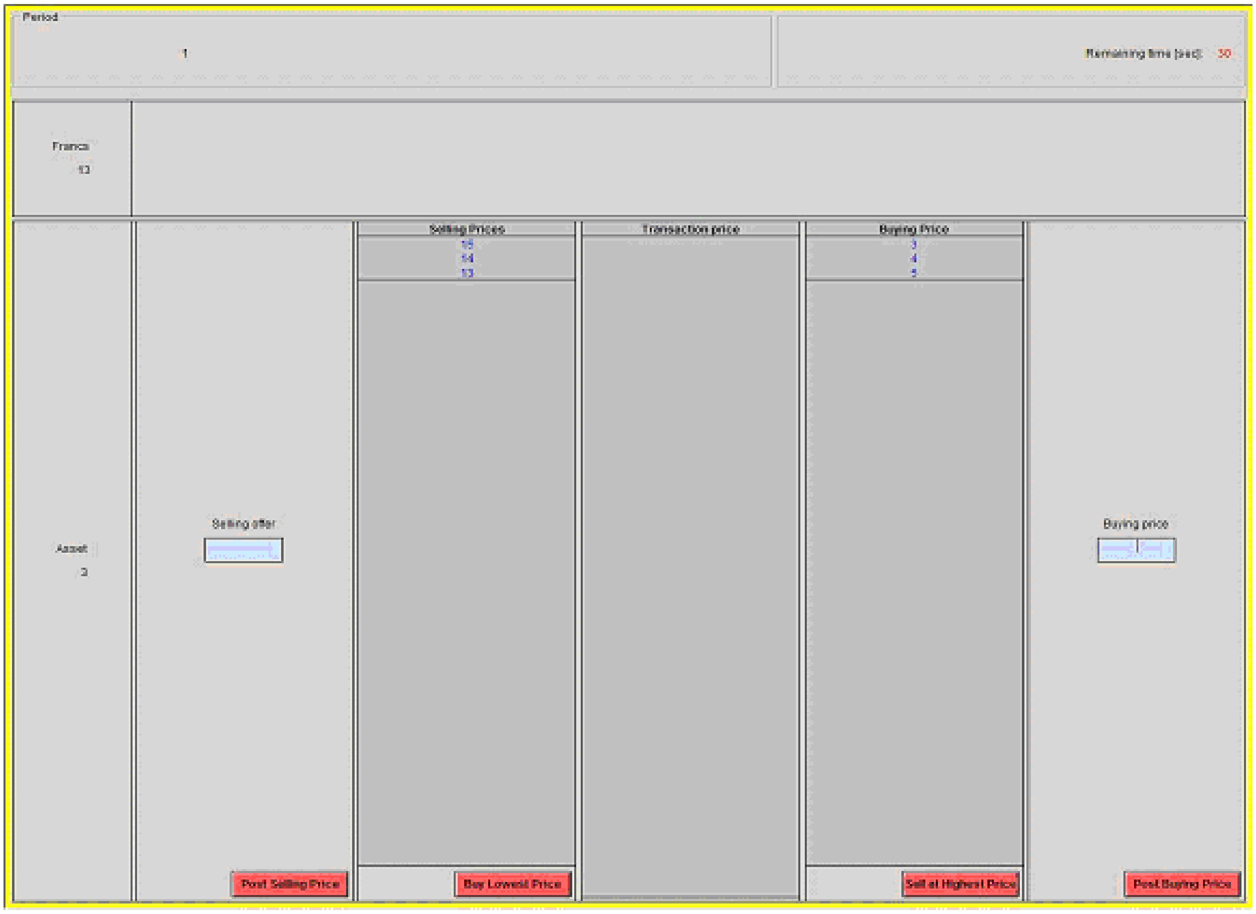
IV. Asset Trading Rules

During each three minute (180 second) trading period, you may choose to buy or sell assets. Trade happens on the trading window screen, show below. The current period is shown in the upper left and the time remaining for trading in this period (in seconds) is indicated in the upper right. The number of francs and assets you have available is shown on the left. Assets are bought and sold one unit at a time, but you can buy or sell more than one unit in a trading period.

To submit a bid or buying price for an asset, type in the amount of francs you are willing to pay for a unit of the asset in the “Buying price” box on the right. Then click on the “Post Buying Price” button on the bottom right. The computer will tell you if you don’t have enough francs to place a buy order; recall that you cannot go below a minimum of 11 francs in your account. Once your buy price has been submitted, it is checked against any other existing buy prices. If your buy price is higher than any existing buy price, it will appear under the “Buying Price” column in the middle right of the screen; otherwise, you will be asked to revise your bid upward - you must improve on existing bids. Once your buy price appears on the trading screen, any player who has a unit of the asset available can choose to sell it to you at that price by using the mouse to highlight your buy price and clicking on the button “Sell at Highest Price” (bottom center-right of the screen). If that happens, the number of francs you bid is transferred to the seller and one unit of the asset is transferred from the seller to you. Another possibility is that another person will choose to improve on the buy price you submitted by entering a higher buy price. In that case, you must increase your buy price even higher to have a chance of buying the asset.

Trading Window Screen

To submit a selling or “ask” price for an asset, type in the amount of francs you would be willing to accept to sell an asset in the “Selling offer” box on the left and then click the “Post Selling Price” button on the bottom left. Note: you cannot sell an asset if you do not presently have an asset available to sell in your account. Once your sell price has been submitted, it is checked against any other existing sell prices. If your sell price is lower than any existing sell prices, it will appear on the trading screen under the ”Selling Price” column in the middle left of the screen; otherwise, you will be asked to revise your sell price downward - you must improve on existing offers to sell. Any participant who has enough francs available can choose to buy the asset from you at your price by using the mouse to highlight your sell price and clicking on the button labeled ”Buy at Lowest Price” (bottom center-left of the screen). If that happens, one unit of the asset is transferred from you to



the buyer, and in exchange the number of francs you agreed to sell the asset for is transferred from the buyer to you. Another possibility is that another person will choose to improve on the sell price you submitted, by entering an even lower sell price. In that case, you will have to lower your sell price even further to have a chance of selling the asset.

Whenever an agreement to buy/sell between any two players takes place, the transaction price is shown in the middle column of the trading screen labeled "Transaction Price." If someone has chosen to buy at the lowest price, all selling prices are cleared from the trading screen. If someone has chosen to sell at the highest price, all buying prices are cleared from the trading screen. As long as trading remains open, you can post new buy and sell prices and agree to make transactions following the same rules given above. The entire history of transaction prices will remain in the middle column for the duration of each trading period.

At the end of each period, you will be told your end-of-period franc balance and dollar payoff for the period, along with your cumulative total dollar payoff over all periods played in the sequence thus far. At then end of each sequence (whenever a "6" is rolled), we will ask you to write down, on your earnings sheet, the sequence number, the number of trading periods in that sequence and your total dollar payoff for that sequence.

V. Final Quiz

Before continuing on to the experiment, we ask that you consider the following scenarios and provide answers to the questions asked in the spaces provided. The numbers used in this quiz are merely illustrative; the actual numbers in the experiment may be quite different. You will need to consult your payoff table to answer some of these questions.

Question 1: Suppose that a sequence has reached period 15. What is the chance that this sequence will continue with another period - period 16? ________________. Would your answer be any different if we replaced 15 with 5 and 16 with 6? Circle one: yes / no.

Question 2: Suppose a sequence ends (a 6 is rolled) and you have n assets. What is the value of those n assets? ________________. Suppose instead, the sequence continued into another period (a 1-5 is rolled)-how many assets would you hold in the next period? ________________.

For questions 3-6 below: suppose at the start of this period you are given 70 francs. In addition, you own 3 assets.

Question 3: What is the maximum number of assets you can sell at the start of the 3-minute trading period? ________________.

Question 4: What is the total number of francs you will have available at the start of the trading period (including francs from assets owned)? ________________. If you do not buy or sell any assets during the 3-minute trading period, what would be your end-of-period dollar payoff? ________________.

Question 5: Now suppose that, during the 3-minute trading period, you sold 2 of your 3 assets: specifically, you sold one asset for a price of 4 francs and the other asset for a price of 8 francs. What is your end-of-period franc total in this case? ________________. What would be your dollar payoff for the period? _______________. What is the number of assets you would have at the start of the next period (if there is one)? _______________.

Question 6: Suppose that instead of selling assets during the trading period (as in question 5), you instead bought one more asset at a price of 18 francs. What would be your end-of-period franc total in this case? _______________. What would be your dollar payoff for the period? _______________. What is the number of assets you will have at the start of the next period (if there is one)? _______________.

VI. Questions

Now is the time for questions. If you have a question about any aspect of the instructions, please raise your hand.

What follows below is the fourth paragraph of the instructions for subjects in the L2 and L3 treatments.

Please open your folder and look at the "Payoff Table" showing how your end-of-period franc balance converts into dollars. The "Payoff Chart" provides a graphical illustration of the payoff table. There are several things to notice. First, the lowest number in the payoff table is **11** francs. You are not permitted to hold less than **11** francs at any time during the experiment. Second, the more francs you earn in a period, the higher will be your dollar earnings for that period. Finally, the dollar payoff from each additional franc that you earn in a period is the same; the formula for converting between francs and dollars is fixed and is given at the bottom of your table.

ENDOWMENT SHEET

[Type 1 subject, $\bar{d} = 2$]

This information is private. Please do not share with others.

Initial franc balance in all odd periods (first, third, fifth, etc.): **110**

Initial franc balance in all even periods (second, fourth, sixth, etc.): **44**

Assets you own in the first period: **1**

Francs paid per asset at start of each period: **2**

Therefore, you will begin the first period with **110 + 1*2 = 112** francs

ENDOWMENT SHEET

[Type 2 subject, $\bar{d} = 2$]

This information is private. Please do not share with others.

Initial franc balance in all odd periods (first, third, fifth, etc.): **24**

Initial franc balance in all even periods (second, fourth, sixth, etc.): **90**

Assets you own in the first period: **4**

Francs paid per asset at start of each period: **2**

Therefore, you will begin the first period with **24 + 4*2 = 32** francs

<u>ENDOWMENT SHEET</u>

[Type 1 subject, $\bar{d} = 3$]

This information is private. Please do not share with others.

Initial franc balance in <u>all</u> odd periods (first, third, fifth, etc.): **110**

Initial franc balance in <u>all</u> even periods (second, fourth, sixth, etc.): **44**

Assets you own in the <u>first</u> period: **1**

Francs paid per asset at start of each period: **3**

Therefore, you will begin the first period with **110 + 1*3 = 113** francs

<u>ENDOWMENT SHEET</u>

[Type 2 subject, $\bar{d} = 3$]

This information is private. Please do not share with others.

Initial franc balance in <u>all</u> odd periods (first, third, fifth, etc.): **24**

Initial franc balance in <u>all</u> even periods (second, fourth, sixth, etc.): **90**

Assets you own in the <u>first</u> period: **4**

Francs paid per asset at start of each period: **3**

Therefore, you will begin the first period with

24 + 4*3 = 36 francs

[Type 1 subject, concave treatments (C2 and C3)]

PAYOFF TABLE

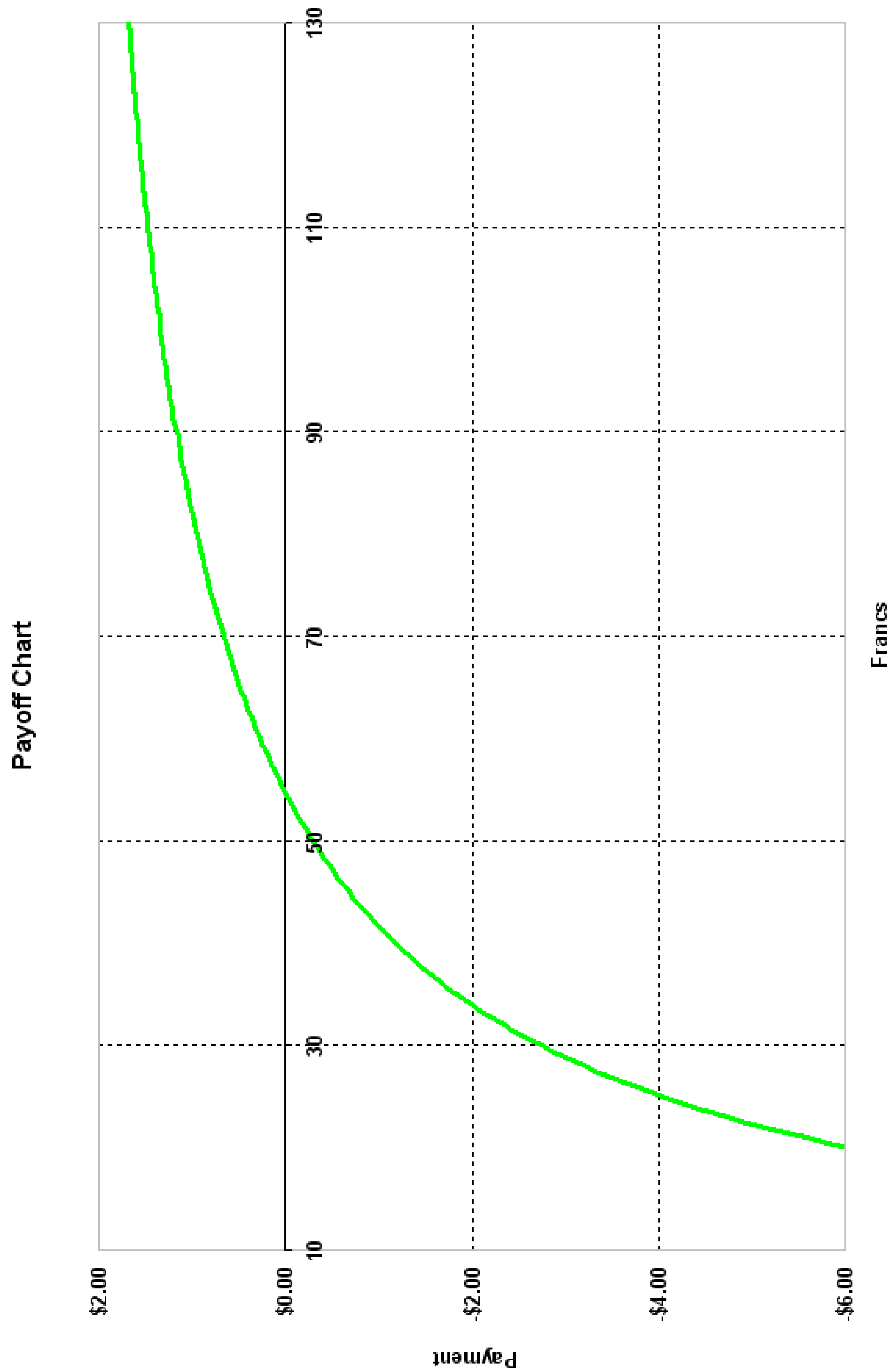
How your end-of-period franc balance converts into dollar earnings

Francs	11	12	13	14	15	16	17	18	19	20
Dollars	-$15.13	-$13.37	-$11.92	-$10.69	-$9.63	-$8.72	-$7.93	-$7.24	-$6.62	-$6.07
Francs	21	22	23	24	25	26	27	28	29	30
Dollars	-$5.58	-$5.14	-$4.74	-$4.37	-$4.04	-$3.74	-$3.46	-$3.20	-$2.96	-$2.74
Francs	31	32	33	34	35	36	37	38	39	40
Dollars	-$2.53	-$2.34	-$2.16	-$2.00	-$1.84	-$1.69	-$1.55	-$1.42	-$1.30	-$1.18
Francs	41	42	43	44	45	46	47	48	49	50
Dollars	-$1.07	-$0.97	-$0.87	-$0.78	-$0.69	-$0.60	-$0.52	-$0.44	-$0.37	-$0.30
Francs	51	52	53	54	55	56	57	58	59	60
Dollars	-$0.23	-$0.16	-$0.10	-$0.04	$0.02	$0.07	$0.12	$0.18	$0.22	$0.27
Francs	61	62	63	64	65	66	67	68	69	70
Dollars	$0.32	$0.36	$0.40	$0.45	$0.49	$0.52	$0.56	$0.60	$0.63	$0.66
Francs	71	72	73	74	75	76	77	78	79	80
Dollars	$0.70	$0.73	$0.76	$0.79	$0.82	$0.85	$0.87	$0.90	$0.93	$0.95
Francs	81	82	83	84	85	86	87	88	89	90
Dollars	$0.98	$1.00	$1.02	$1.05	$1.07	$1.09	$1.11	$1.13	$1.15	$1.17
Francs	91	92	93	94	95	96	97	98	99	100
Dollars	$1.19	$1.21	$1.22	$1.24	$1.26	$1.28	$1.29	$1.31	$1.32	$1.34
Francs	101	102	103	104	105	106	107	108	109	110
Dollars	$1.35	$1.37	$1.38	$1.40	$1.41	$1.42	$1.44	$1.45	$1.46	$1.48
Francs	111	112	113	114	115	116	117	118	119	120
Dollars	$1.49	$1.50	$1.51	$1.52	$1.53	$1.55	$1.56	$1.57	$1.58	$1.59
Francs	121	122	123	124	125	126	127	128	129	130
Dollars	$1.60	$1.61	$1.62	$1.63	$1.64	$1.65	$1.65	$1.66	$1.67	$1.68

The conversion formula is: Dollars =2.6074 -311.34*(Francs^(-1.195)). If your end of period franc balance exceeds 130, we will use this formula to calculate your earnings.

Note: Your franc balance cannot fall below 11 francs.

[Type 1 subject, concave treatments (C2 and C3)]



[Type 2 subject, concave treatments (C2 and C3)]

PAYOFF TABLE

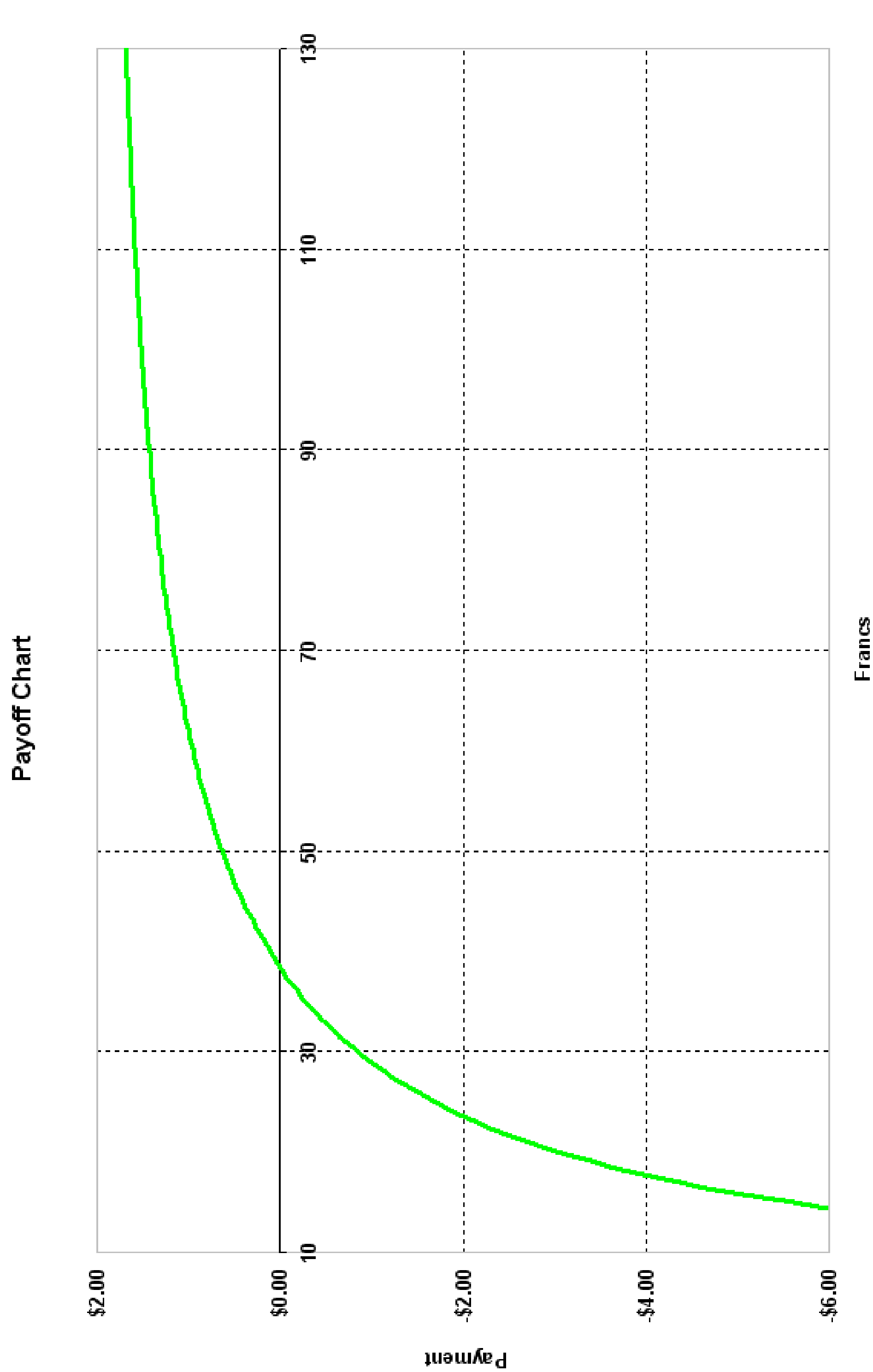
How your end-of-period franc balance converts into dollar earnings

Francs	11	12	13	14	15	16	17	18	19	20
Dollars	-$9.67	-$8.33	-$7.24	-$6.33	-$5.56	-$4.91	-$4.35	-$3.86	-$3.43	-$3.05
Francs	21	22	23	24	25	26	27	28	29	30
Dollars	-$2.72	-$2.42	-$2.15	-$1.91	-$1.69	-$1.49	-$1.31	-$1.14	-$0.99	-$0.85
Francs	31	32	33	34	35	36	37	38	39	40
Dollars	-$0.72	-$0.60	-$0.49	-$0.38	-$0.29	-$0.20	-$0.11	-$0.03	$0.04	$0.11
Francs	41	42	43	44	45	46	47	48	49	50
Dollars	$0.18	$0.24	$0.30	$0.35	$0.40	$0.45	$0.50	$0.55	$0.59	$0.63
Francs	51	52	53	54	55	56	57	58	59	60
Dollars	$0.67	$0.71	$0.74	$0.78	$0.81	$0.84	$0.87	$0.90	$0.92	$0.95
Francs	61	62	63	64	65	66	67	68	69	70
Dollars	$0.98	$1.00	$1.02	$1.05	$1.07	$1.09	$1.11	$1.13	$1.15	$1.16
Francs	71	72	73	74	75	76	77	78	79	80
Dollars	$1.18	$1.20	$1.22	$1.23	$1.25	$1.26	$1.28	$1.29	$1.30	$1.32
Francs	81	82	83	84	85	86	87	88	89	90
Dollars	$1.33	$1.34	$1.35	$1.37	$1.38	$1.39	$1.40	$1.41	$1.42	$1.43
Francs	91	92	93	94	95	96	97	98	99	100
Dollars	$1.44	$1.45	$1.46	$1.47	$1.48	$1.48	$1.49	$1.50	$1.51	$1.52
Francs	101	102	103	104	105	106	107	108	109	110
Dollars	$1.52	$1.53	$1.54	$1.54	$1.55	$1.56	$1.56	$1.57	$1.58	$1.58
Francs	111	112	113	114	115	116	117	118	119	120
Dollars	$1.59	$1.60	$1.60	$1.61	$1.61	$1.62	$1.62	$1.63	$1.63	$1.64
Francs	121	122	123	124	125	126	127	128	129	130
Dollars	$1.64	$1.65	$1.65	$1.66	$1.66	$1.67	$1.67	$1.67	$1.68	$1.68

The conversion formula is: Dollars =2.0627 -327.81*(Francs^ (-1.388)). If your end of period franc balance exceeds 130, we will use this formula to calculate your earnings.

Note: Your franc balance cannot fall below 11 francs.

[Type 2 subject, concave treatments (C2 and C3)]



[Type 1 subject, linear treatments (L2 and L3)]

PAYOFF TABLE

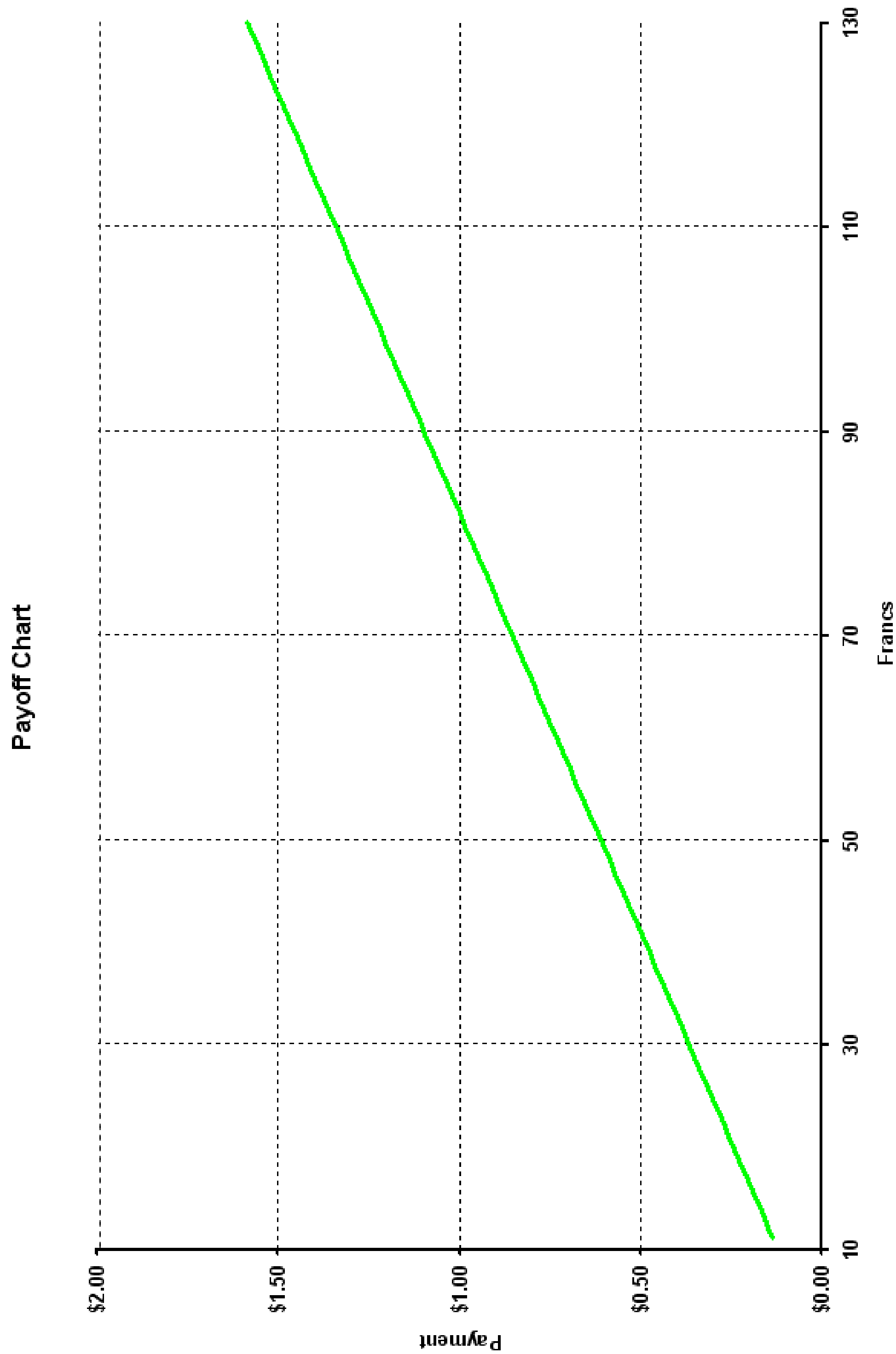
How your end-of-period franc balance converts into dollar earnings

Francs	11	12	13	14	15	16	17	18	19	20
Dollars	$0.13	$0.15	$0.16	$0.17	$0.18	$0.20	$0.21	$0.22	$0.23	$0.24
Francs	21	22	23	24	25	26	27	28	29	30
Dollars	$0.26	$0.27	$0.28	$0.29	$0.30	$0.32	$0.33	$0.34	$0.35	$0.37
Francs	31	32	33	34	35	36	37	38	39	40
Dollars	$0.38	$0.39	$0.40	$0.41	$0.43	$0.44	$0.45	$0.46	$0.48	$0.49
Francs	41	42	43	44	45	46	47	48	49	50
Dollars	$0.50	$0.51	$0.52	$0.54	$0.55	$0.56	$0.57	$0.59	$0.60	$0.61
Francs	51	52	53	54	55	56	57	58	59	60
Dollars	$0.62	$0.63	$0.65	$0.66	$0.67	$0.68	$0.70	$0.71	$0.72	$0.73
Francs	61	62	63	64	65	66	67	68	69	70
Dollars	$0.74	$0.76	$0.77	$0.78	$0.79	$0.80	$0.82	$0.83	$0.84	$0.85
Francs	71	72	73	74	75	76	77	78	79	80
Dollars	$0.87	$0.88	$0.89	$0.90	$0.91	$0.93	$0.94	$0.95	$0.96	$0.98
Francs	81	82	83	84	85	86	87	88	89	90
Dollars	$0.99	$1.00	$1.01	$1.02	$1.04	$1.05	$1.06	$1.07	$1.09	$1.10
Francs	91	92	93	94	95	96	97	98	99	100
Dollars	$1.11	$1.12	$1.13	$1.15	$1.16	$1.17	$1.18	$1.20	$1.21	$1.22
Francs	101	102	103	104	105	106	107	108	109	110
Dollars	$1.23	$1.24	$1.26	$1.27	$1.28	$1.29	$1.30	$1.32	$1.33	$1.34
Francs	111	112	113	114	115	116	117	118	119	120
Dollars	$1.35	$1.37	$1.38	$1.39	$1.40	$1.41	$1.43	$1.44	$1.45	$1.46
Francs	121	122	123	124	125	126	127	128	129	130
Dollars	$1.48	$1.49	$1.50	$1.51	$1.52	$1.54	$1.55	$1.56	$1.57	$1.59

The conversion formula is: Dollars =0.0122xFrancs. If your end of period franc balance exceeds 130, we will use this formula to calculate your earnings.

Note: Your franc balance cannot fall below 11 francs.

[Type 1 subject, linear treatments (L2 and L3)]



[Type 2 subject, linear treatments (L2 and L3)]

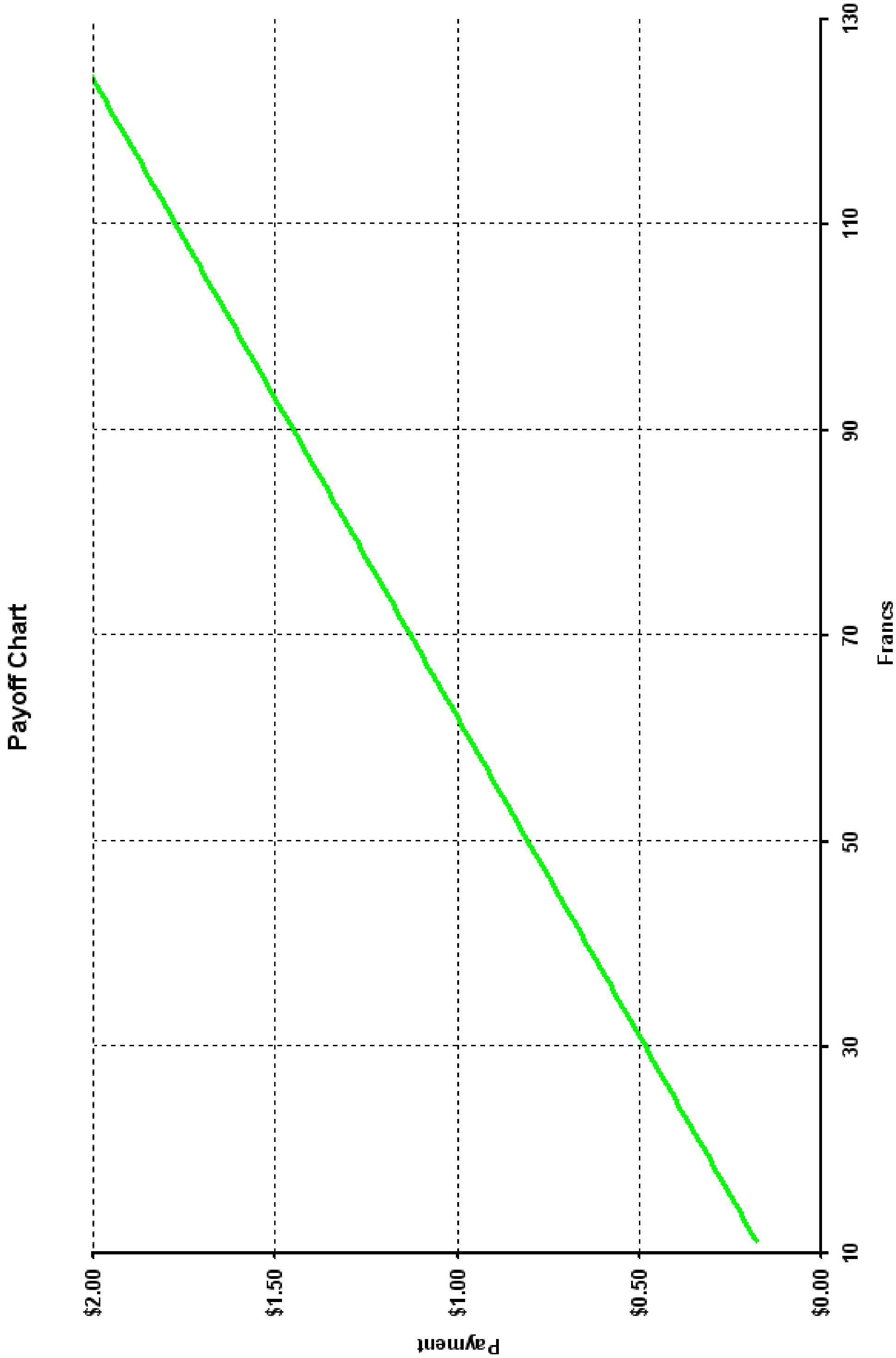
PAYOFF TABLE

How your end-of-period franc balance converts into dollar earnings

Francs	11	12	13	14	15	16	17	18	19	20
Dollars	\$0.18	\$0.19	\$0.21	\$0.23	\$0.24	\$0.26	\$0.27	\$0.29	\$0.31	\$0.32
Francs	21	22	23	24	25	26	27	28	29	30
Dollars	\$0.34	\$0.35	\$0.37	\$0.39	\$0.40	\$0.42	\$0.44	\$0.45	\$0.47	\$0.48
Francs	31	32	33	34	35	36	37	38	39	40
Dollars	\$0.50	\$0.52	\$0.53	\$0.55	\$0.56	\$0.58	\$0.60	\$0.61	\$0.63	\$0.65
Francs	41	42	43	44	45	46	47	48	49	50
Dollars	\$0.66	\$0.68	\$0.69	\$0.71	\$0.73	\$0.74	\$0.76	\$0.77	\$0.79	\$0.81
Francs	51	52	53	54	55	56	57	58	59	60
Dollars	\$0.82	\$0.84	\$0.85	\$0.87	\$0.89	\$0.90	\$0.92	\$0.94	\$0.95	\$0.97
Francs	61	62	63	64	65	66	67	68	69	70
Dollars	\$0.98	\$1.00	\$1.02	\$1.03	\$1.05	\$1.06	\$1.08	\$1.10	\$1.11	\$1.13
Francs	71	72	73	74	75	76	77	78	79	80
Dollars	\$1.15	\$1.16	\$1.18	\$1.19	\$1.21	\$1.23	\$1.24	\$1.26	\$1.27	\$1.29
Francs	81	82	83	84	85	86	87	88	89	90
Dollars	\$1.31	\$1.32	\$1.34	\$1.35	\$1.37	\$1.39	\$1.40	\$1.42	\$1.44	\$1.45
Francs	91	92	93	94	95	96	97	98	99	100
Dollars	\$1.47	\$1.48	\$1.50	\$1.52	\$1.53	\$1.55	\$1.56	\$1.58	\$1.60	\$1.61
Francs	101	102	103	104	105	106	107	108	109	110
Dollars	\$1.63	\$1.65	\$1.66	\$1.68	\$1.69	\$1.71	\$1.73	\$1.74	\$1.76	\$1.77
Francs	111	112	113	114	115	116	117	118	119	120
Dollars	\$1.79	\$1.81	\$1.82	\$1.84	\$1.85	\$1.87	\$1.89	\$1.90	\$1.92	\$1.94
Francs	121	122	123	124	125	126	127	128	129	130
Dollars	\$1.95	\$1.97	\$1.98	\$2.00	\$2.02	\$2.03	\$2.05	\$2.06	\$2.08	\$2.10

The conversion formula is: Dollars =0.0161xFrancs. If your end of period franc balance exceeds 130, we will use this formula to calculate your earnings.
Note: Your franc balance cannot fall below 11 francs.

[Type 2 subject, linear treatments (L2 and L3)]



Holt-Laury Paired Lottery Task Instructions

You will face a sequence of 10 decisions. Each decision is a paired choice between two options, labeled "Option A" and "Option B". For each decision you must choose either Option A or Option B. You do this by clicking next to the radio button corresponding to your choice on the computer screen. After making your choice, please also record it on the attached record sheet under the appropriate headings.

The sequence of 10 decisions you will face are as follows:

Decision	Option A	Option B
1	Receive \$6.00 10 out of 100 draws OR Receive \$4.80 90 out of 100 draws	Receive \$11.55 10 out of 100 draws OR Receive \$ 0.30 90 out of 100 draws
2	Receive \$6.00 20 out of 100 draws OR Receive \$4.80 80 out of 100 draws	Receive \$11.55 20 out of 100 draws OR Receive \$ 0.30 80 out of 100 draws
3	Receive \$6.00 30 out of 100 draws OR Receive \$4.80 70 out of 100 draws	Receive \$11.55 30 out of 100 draws OR Receive \$ 0.30 70 out of 100 draws
4	Receive \$6.00 40 out of 100 draws OR Receive \$4.80 60 out of 100 draws	Receive \$11.55 40 out of 100 draws OR Receive \$ 0.30 60 out of 100 draws
5	Receive \$6.00 50 out of 100 draws OR Receive \$4.80 50 out of 100 draws	Receive \$11.55 50 out of 100 draws OR Receive \$ 0.30 50 out of 100 draws
6	Receive \$6.00 60 out of 100 draws OR Receive \$4.80 40 out of 100 draws	Receive \$11.55 60 out of 100 draws OR Receive \$ 0.30 40 out of 100 draws
7	Receive \$6.00 70 out of 100 draws OR Receive \$4.80 30 out of 100 draws	Receive \$11.55 70 out of 100 draws OR Receive \$ 0.30 30 out of 100 draws
8	Receive \$6.00 80 out of 100 draws OR Receive \$4.80 20 out of 100 draws	Receive \$11.55 80 out of 100 draws OR Receive \$ 0.30 20 out of 100 draws
9	Receive \$6.00 90 out of 100 draws OR Receive \$4.80 10 out of 100 draws	Receive \$11.55 90 out of 100 draws OR Receive \$ 0.30 10 out of 100 draws
10	Receive \$6.00 100 out of 100 draws OR Receive \$4.80 0 out of 100 draws	Receive \$11.55 100 out of 100 draws OR Receive \$ 0.30 0 out of 100 draws

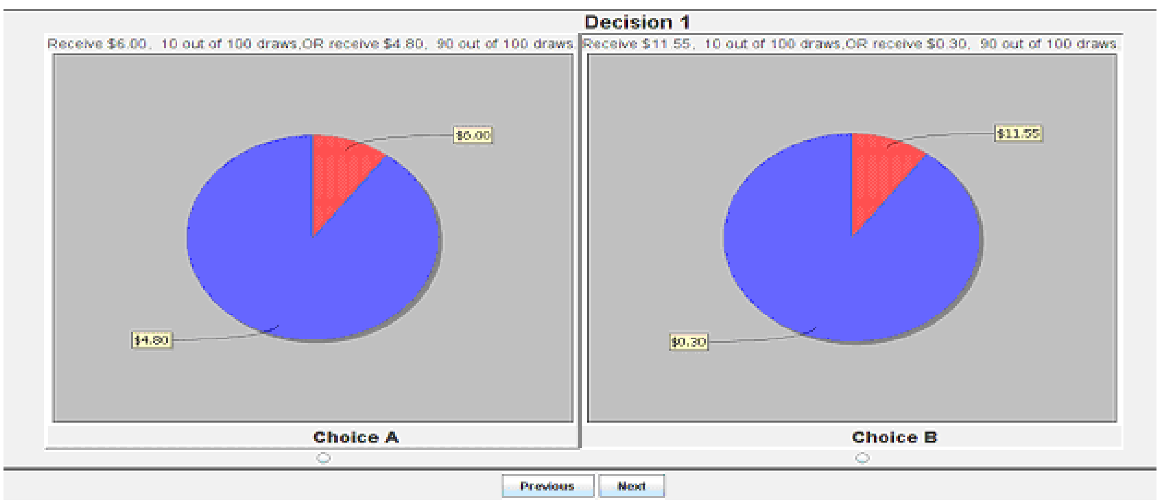
After you have made all 10 decisions, the computer program will randomly select 1 of the 10 decisions and your choice for that decision will be used to determine your payoff. All 10 decisions have the same chance of being chosen.

Notice that for each decision, the two options describe two different amounts of money you can receive, depending on a random draw. The random draw will be made by the computer and will be a number (integer) from 1 to 100 inclusive. Consider Decision 1. If you choose

Option A, then you receive \$6.00 if the random number drawn is 10 or less, that is, in 10 out of 100 possible random draws made by the computer, or 10 percent of the time, while you receive \$4.80 if the random number is between 11 and 100, that is in 90 out of 100 possible random draws made by the computer, or 90 percent of the time. If you choose Option B, then you receive \$11.55 if the random number drawn is 10 or less, that is, in 10 out of 100 possible random draws made by the computer, while you receive \$0.30 if the random number is between 11 and 100, that is in 90 out of 100 possible random draws made by the computer, or 90 percent of the time. Other decisions are similar, except that your chances of receiving the higher payoff for each option increase. Notice that all decisions except decision 10 involve random draws. For decision 10, you face a certain (100 percent) chance of \$6.00 if you choose Option A or a certain (100 percent) chance of \$11.55 if you choose Option B.

Even though you make 10 decisions, only ONE of these decisions will be used to determine your earnings from this experiment. All 10 decisions have an equal chance of being chosen to determine your earnings. You do not know in advance which of these decisions will be selected.

Consider again decision 1. This will appear to you on your computer screen as follows:



The pie charts help you to visualize your chances of receiving the two amounts presented by each option. When you are ready to make a decision, simply click on the button below the option you wish to choose. Please also circle your choice for each of the 10 decisions on your record sheet. When you are satisfied with your choice, click the Next button to move on to the next decision. You may choose Option A for some decisions and Option B for others and you may change your decisions or make them in any order using the Previous and Next buttons.

When you have completed all 10 choices, and you are satisfied with those choices you will need to click the Confirm button that appears following decision 10. The program will check that you have made all 10 decisions; if not, you will need to go back to any incomplete decisions and complete those decisions which you can do using the Previous button. You can also go back and change any of your decisions prior to clicking the confirm button by using the Previous button.

Once you have made all 10 decisions and clicked the Confirm button, the results screen will tell you the decision number 1, 2,. . . 10, that was randomly selected by the computer program. Your choice of option A or B for that decision (and that decision only) will then be used to determine your dollar payoff. Specifically, the computer will draw a random number between 1 and 100 (all numbers have an equal chance) and report to you both the random number drawn and the payoff from your option choice.

Your payoff will be added to the amount you have already earned in today's experiment. Please circle the decision that was chosen for payment on your record sheet and write down both the random number drawn by the computer program and the amount you earned from the option you chose for that decision on your record sheet. On the computer monitor, type in your subject ID number, which is the same number used to identify you in the first experiment in today's session. Then click the "Save and Close" button.

Are there any questions before we begin?

Please do not talk with anyone while these decisions are being made. If you have a question while making decisions, please raise your hand.

Record Sheet Player ID Number______

Decision 1	Circle Option Choice A B
Decision 2	Circle Option Choice A B
Decision 3	Circle Option Choice A B
Decision 4	Circle Option Choice A B
Decision 5	Circle Option Choice A B
Decision 6	Circle Option Choice A B
Decision 7	Circle Option Choice A B
Decision 8	Circle Option Choice A B
Decision 9	Circle Option Choice A B
Decision 10	Circle Option Choice A B

At the end of this experiment, circle the Decision number selected by the computer program for payment. Write down the random number drawn for the selected decision (between 1 and 100): ________________ Write down your payment earned for this part of the experiment: $________________

Individual Choice Experimental Instructions

Note: These instructions are for the individual choice, concave, $d = 2$ treatment where the price of the asset, was fixed at $p = 10$ (treatment C2-10). Instructions for the other individual choice treatments are similar.

I. Overview

This is an experiment in the economics of decision making. If you follow the instructions carefully and make good decisions you may earn a considerable amount of money that will be paid to you in cash at the end of this session. Please do not talk with others for the duration of the experiment. If you have a question please raise your hand and one of the experimenters will answer your question in private.

Today you will participate in one or more "sequences", each consisting of a number of "trading periods". There are two objects of interest in this experiment, francs and assets. At the start of each period you will receive the number of francs as indicated on the page entitled "Endowment Sheet". In addition, you will earn a "dividend" of 2 francs for each unit of the asset you hold at the start of a period (please look at the endowment sheet now). During the period you may buy or sell assets using francs at the price listed on the endowment sheet. Details about how this is done are discussed below in section IV.

At the end of each period, your end-of-period franc balance will be converted into dollar earnings. These dollar earnings will accumulate across periods and sequences, and will be paid to you in cash at the end of the experiment. The number of assets you own carry over from one period to the next, if there is a next period (more on this below), whereas your end-of-period franc balance does not you start each new period with the endowment of francs indicated on your Endowment Sheet. Therefore, there are two reasons to hold assets: (1) they provide additional francs at the beginning of each period and (2) assets may be sold for francs in some future period.

Please open your folder and look at the "Payoff Table" showing how your end-of-period franc balance converts into dollars. The "Payoff Chart" provides a graphical illustration of the payoff table. [*Note these are the same tables and charts used in the Market Experiment - specifically here, refer to those for the Type 1 subject, concave treatments (C2 and C3) show above.*] There are several things to notice. First, very low numbers of francs yield negative dollar payoffs. The lowest number in the payoff table is 11 francs. You are not permitted to hold less than 11 francs at any time during the experiment. Second, the more francs you earn in a period, the higher will be your dollar earnings for that period. Finally, the dollar payoff from each additional franc that you earn in a period is diminishing; for example, the payoff difference between 56 and 57 francs is larger than the difference between 93 and 94 francs.

II. Preliminary Quiz

Using your endowment sheet and payoff table, we now pause and ask you to answer the following questions. We will come around to verify that your answers are correct.

1. Suppose it is the first period of a sequence (an odd-numbered period). What is the number of assets you own? __________.

2. What is the total number of francs you have available at the start of the first period, including both your endowment of francs and the 2 francs you get for each unit of the asset you own at the start of the period? _________.

3. Suppose that at the end of the first period you have not bought or sold any assets, so your franc total is the same as at the start of the period (your answer to question 2). What is your payoff in dollars for this first period? _________.

4. Suppose that the sequence continues with period 2 (an even-numbered period), and that you did not buy or sell any assets in the first period, so you own the same number of assets. What is the total number of francs you have available at the start of period 2, including both your endowment of francs and the 2 francs you get for each unit of the asset you own at the start of a period? _________.

5. Suppose again that at the end of period 2 you have not bought or sold any assets, so your franc total is the same as at the start of the period (your answer to question 4). What is your payoff in dollars for this second period? _________. What would be your dollar earnings in the sequence to this point? _________.

III. Sequences of Trading Periods

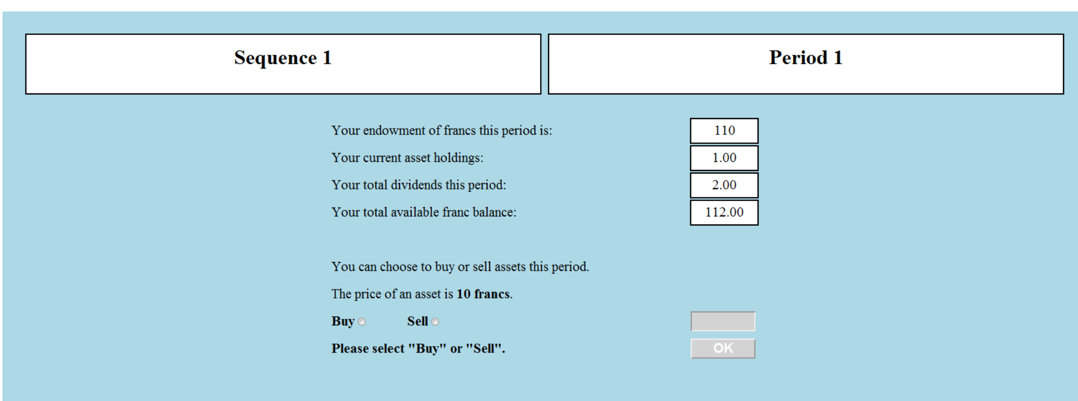
As mentioned, todays session consists of one or more “sequences,” with each sequence consisting of a number of “periods.” Each period will last approximately 2 minutes. At the end of each period your end-of-period franc balance, dollar payoff and the number of assets will be shown to you on your computer screen. One of the participants will then roll a die (with sides numbered from 1-6). If the number rolled is 1-5, the sequence will continue with a new trading period. If a 6 is rolled, the sequence will end and your cash balance for that sequence will be final. Any assets you own will become worthless. Thus, at the start of each period, there is a 1 in 6 (or about 16.7 percent) chance that the period will be the last one played in the sequence and a 5 in 6 (or about 83.3 percent) chance that the sequence will continue with another period.

If fewer than 14 total periods have occurred in this experiment, a new sequence will begin. You will start the new sequence and every new sequence just as you started the first sequence, with the number of francs and assets as indicated on your endowment sheet. The quantity of francs you receive in each period will alternate as before, between odd and even periods. If at least 14 periods have taken place since the start of the experiment, then the current sequence will be the last sequence played; that is, the next time a 6 is rolled the sequence will end and the experiment will be over. The total dollar amount you earned from all sequences will be calculated and you will be paid this amount together with your $5 show-up fee in cash and in private before exiting the room.

If, by chance, the final sequence has not ended by the three-hour period for which you have been recruited, we will schedule a continuation of this sequence for another time in which everyone here can attend. You would be immediately paid your earnings from all sequences that ended in todays session. You would start the continuation sequence with the same number of assets you ended with in todays session, and your franc balance would continue to alternate between odd and even periods as before. You would be paid your earnings for this final sequence after it has been completed.

IV. Asset Trading Rules

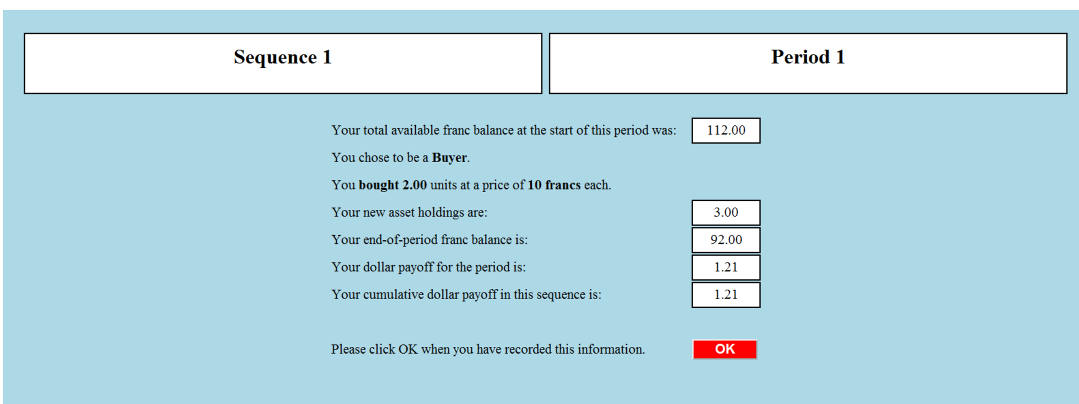
You will make your decision to buy or sell assets by entering information into the Pre-Trade Window, an example of which is presented below. The current sequence appears in the upper-left corner of the screen, the current period number in the right. The next four lines within the window provide you with information regarding your franc and asset position at the beginning of the period. For example, in the window below, you would begin the current period with an endowment of 110 francs and 1 unit of the asset. Since each unit of the asset pays an additional 2 francs, your total available francs to start the period would be 112.



Below this information you are reminded of the price of each unit of the asset (in this example the price is 10 francs, but the price you will actually use is presented on your Endowment

Sheet), and you are asked to decide whether you'd like to buy or sell units of the assets at this price. In the example below, the "Buy" button has been selected. After you have decided whether you will be a buyer or a seller, you will enter how many units of the asset you'd like to trade. Recall that you cannot sell a greater quantity of assets than you currently possess, and that you cannot buy so many units of the asset that your current franc balance would drop below 11. If you would like to trade nothing in this period, choose the Buy or Sell button (it doesn't matter which one) and enter a quantity of 0. Once you have entered your desired quantity, click the red "OK" button to complete the transaction. When you click this button, your decision is final.

After you have made your trading decision, you will be presented with a new window, as depicted in the Post-Trade Window below. In this example, you have made the decision to buy two units of the asset. Since you started the period with 112 francs, and since assets cost 10 francs each, you would end the period with 112 10*2 = 92 francs and 3 units of the asset (recall that you started the period with one unit). Your dollar payoff for the period, based on your end-of-period franc balance of 92 francs, would be $1.21 (you can confirm this amount on your Payoff Table). Your cumulative earnings over all periods in the current sequence are also displayed. Please write this number down on your earnings sheet in the appropriate column.



After all participants have recorded their cumulative earnings and clicked the OK button, a die will be rolled to determine if the sequence will continue. On a roll of 1-5, the sequence will continue, and your asset position as of the end of the last period will be your initial asset position in the new period. You would begin the next period of the sequence with your endowment income (in the example above, you would begin period 2 with endowment income of 44 francs, as stated on your Endowment Sheet), dividend income (in this example 6 francs, because you hold 3 units of the asset, and each unit pays a dividend of 2 francs), and your assets from the previous period (in this example, 3 units). On a roll of "6" the sequence is over and your assets have zero value. Depending on the total number of rounds played, a new sequence may or may not begin.

V. Final Quiz

Before continuing on to the experiment, we ask that you consider the following scenarios and provide answers to the questions asked in the spaces provided. The numbers used in this quiz are merely illustrative; the actual numbers in the experiment may be quite different. You will need to consult your payoff table to answer some of these questions.

Question 1: Suppose that a sequence has reached period 15. What is the chance that this sequence will continue with another period period 16? _________ Would your answer be any different if we replaced 15 with 5 and 16 with 6? Circle one: yes / no.

Question 2: Suppose a sequence ends (a 6 is rolled) and you have n assets. What is the value of those n assets? _________. Suppose instead, the sequence continued into another period (a 1-5 is rolled)how many assets would you hold in the next period? _________.

For questions 3-6 below: suppose at the start of this period you are given 70 francs. In addition, you own 3 assets.

Question 3: What is the maximum number of assets you can sell in the trading period? _________.

Question 4: What is the total number of francs you will have available at the start of the trading period (including francs from assets owned)? _________ . If you do not buy or sell any assets during the trading period, what would be your end-of-period dollar payoff? _________ .

Question 5: Now suppose that you sold 2 of your 3 assets during the trading period at a price of 8 francs. What is your end-of-period franc total in this case? _________. What would be your dollar payoff for the period? _________. What is the number of assets you would have at the start of the next period (if there is one)? _________.

Question 6: Suppose that instead of selling assets during the trading period (as in question 5), you instead bought one more asset at a price of 18 francs. What would be your end-of-period franc total in this case? _________. What would be your dollar payoff for the period?_________. What is the number of assets you will have at the start of the next period (if there is one)? _________.

VI. Questions

Now is the time for questions. If you have a question about any aspect of the instructions, please raise your hand.