Are Long-Horizon Expectations (De-)Stabilizing? Theory and Experiments
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On-line Supplementary Materials: Appendices

George W. Evans* Cars Hommes† Bruce McGough‡
Isabelle Salle§

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*Department of Economics, University of Oregon & School of Economics and Finance, University of St Andrews.

†Amsterdam School of Economics, University of Amsterdam, Tinbergen Institute & Bank of Canada, Ottawa.

‡Department of Economics, University of Oregon.

§Department of Economics,University of Ottawa, ON, CA, Amsterdam School of Economics, University of Amsterdam & Tinbergen Institute, the Netherlands.

A Finite-horizon learning in the Lucas model

Section A of this appendix provides further discussion of the theoretical model developed in Section 2, and includes the proofs of the propositions and corollaries.

A.1 Expected wealth target assumption: $q^e_{it+T} = q_{it-1}$

We adopt the follow principle: if, at a given time t, current price and expected future prices coincide with the PF steady state, then the agent's decision rule should reproduce fully optimal behavior.[1] We can use this principle to derive the most parsimonious wealth forecasting model. In the PF steady state rational agents hold wealth constant and consume their dividends. Thus our agents anticipate that their wealth at the end of their planning horizons coincides with their current holdings: $q^e_{it+T} = q_{it-1}$. Further details of the dynamic implications of this behavioral assumptions are discussed in Appendix A.3.

A.2 Preparatory work for Proposition 2.1

Because we will work with both levels and deviations it is helpful to introduce new notation: we let dx be the deviation of a variable x from its steady-state value. Thus, for example, Proposition 2.1 becomes

Proposition 2.1 *There exist type-specific expectation feedback parameters $\xi_i > 0$ such that $\xi \equiv \sum_i \xi_i < 1$ and $dp_t = \sum_i \xi_i \cdot d\bar{p}^e_{it}(T_i)$.*

We begin with following lemma providing the first-order approximation to the time t asset demand dq_t in terms of contemporaneous variables dp_t and dp_{t-1}, and expected future variables dp^e_{t+k} and dq^e_{t+T}. Here we do not yet impose our expected wealth target assumption, and we have dropped the agent index i for convenience.

Lemma 1. *Let $\sigma = -cu''(c)/u'(c)$. Then*

$$dq_t \;=\; g(T)dq_{t-1} - \phi g(T)dp_t + T^{-1}h(T)dq^e_{t+T} + \phi h(T)\left(\frac{1}{T}\sum_{k=1}^{T} dp^e_{t+k}\right), \quad \text{(A.1)}$$

[1] This can be viewed as a bounded optimality extension of the principle for forecast rules introduced by Grandmont and Laroque (1986), which in particular required that forecast rules be able to reproduce steady states.

where

$$\phi = \frac{(1-\beta)q}{p\sigma},\ g(T) = \frac{1-\beta^T}{1-\beta^{T+1}},\ \textit{and}\ h(T) = \frac{(1-\beta)T\beta^T}{1-\beta^{T+1}}.$$

Proof of Lemma 1 Without loss of generality, let $t=0$. Let $Q_k = p_k q_k$, and $R_k = p_{k-1}^{-1}(p_k + y_k)$, so that $c_k + Q_k = R_k Q_{k-1}$. The associated first-order condition (FOC) is $u'(c_k) = \beta R_{k+1} u'(c_{k+1})$. Linearizing the FOC and iterating gives

$$\begin{aligned} dc_k &= dc_{k-1} + \frac{(1-\beta)Q}{\sigma} dR_k, \text{ or} \\ dc_k &= dc_0 + \frac{(1-\beta)Q}{\sigma} \sum_{m=1}^{k} dR_m. \end{aligned} \tag{A.2}$$

Linearizing $c_k + Q_k = R_k Q_{k-1}$ and iterating gives

$$\begin{aligned} dc_k &= RdQ_{k-1} - dQ_k + QdR_k, \text{ or} \\ \sum_{k=0}^{T} \beta^k dc_k &= RdQ_{-1} - \beta^T dQ_T + Q \sum_{k=0}^{T} \beta^k dR_k, \end{aligned} \tag{A.3}$$

where $R = \beta^{-1}$. Combining (A.2) and (A.3), we get

$$\sum_{k=0}^{T} \beta^k \left(dc_0 + \frac{(1-\beta)Q}{\sigma} \sum_{m=1}^{k} dR_m \right) = RdQ_{-1} - \beta^T dQ_T + Q \sum_{k=0}^{T} \beta^k dR_k,$$

or

$$\left(\frac{1-\beta^{T+1}}{1-\beta}\right) dc_0 = RdQ_{-1} - \beta^T dQ_T + Q \sum_{k=0}^{T} \beta^k dR_k - \frac{(1-\beta)Q}{\sigma} \sum_{k=0}^{T} \beta^k \sum_{m=1}^{k} dR_m.$$

Now notice

$$\sum_{k=0}^{T} \beta^k \sum_{m=1}^{k} dR_m = \sum_{k=1}^{T} \left(\frac{\beta^k - \beta^{T+1}}{1-\beta}\right) dR_k.$$

It follows that

$$dc_0 = \frac{1-\beta}{1-\beta^{T+1}} \left(RdQ_{-1} - \beta^T dQ_T + QdR_0 + \frac{Q}{\sigma} \sum_{k=1}^{T} \psi(k,T) dR_k \right), \tag{A.4}$$

where $\psi(k,T) = \beta^k(\sigma - 1) + \beta^{T+1}$.

The linearized flow constraint provides

$$dQ_0 = RdQ_{-1} + QdR_0 - dc_0.$$

Combine with A.4 to get

$$\begin{aligned} dQ_0 &= R\left(\frac{\beta(1-\beta^T)}{1-\beta^{T+1}}\right)dQ_{-1} + Q\left(\frac{\beta(1-\beta^T)}{1-\beta^{T+1}}\right)dR_0 \\ &\quad + \left(\frac{\beta^T(1-\beta)}{1-\beta^{T+1}}\right)dQ_t - \left(\frac{1-\beta}{1-\beta^{T+1}}\right)\left(\frac{Q}{\sigma}\right)\sum_{k=1}^{T}\psi(k,T)dR_k, \\ &\text{or} \\ dQ_0 &= \phi_0(T)dQ_{-1} + \phi_1(T)dR_0 + \phi_2(T)dQ_t + \phi_3(T)\sum_{k=1}^{T}\psi(k,T)dR_k. \end{aligned}$$

Next, linearize the relationship between prices, dividends and returns:

$$dR_k = \frac{1}{p}(dp_k + dy_k - Rdp_{k-1}).$$

Since $\beta R = 1$, we may compute

$$\begin{aligned} \sum_{k=1}^{T}\beta^k(dp_k - Rdp_{k-1}) &= \beta^T dp_T - dp_0 \\ \sum_{k=1}^{T}(dp_k - Rdp_{k-1}) &= dp_T - Rdp_0 - R(1-\beta)\sum_{k=1}^{T-1}dp_k. \end{aligned}$$

It follows that $\sum_{k=1}^{T}\psi(k,T)dR_k$

$$\begin{aligned} &= \frac{1}{p}\sum_{k=1}^{T}\psi(k,T)dy_k + \frac{\sigma-1}{p}\sum_{k=1}^{T}\beta^k(dp_k - Rdp_{k-1}) + \frac{\beta^{T+1}}{p}\sum_{k=1}^{T}(dp_k - Rdp_{k-1}) \\ &= \frac{1}{p}\sum_{k=1}^{T}\psi(k,T)dy_k + \frac{\sigma-1}{p}\left(\beta^T dp_T - dp_0\right) + \frac{\beta^{T+1}}{p}\left(dp_T - Rdp_0 - R(1-\beta)\sum_{k=1}^{T-1}dp_k\right) \\ &= \frac{1}{p}\sum_{k=1}^{T}\psi(k,T)dy_k + \frac{\beta^T}{p}(\sigma-1+\beta)dp_T - \frac{1}{p}(\sigma-1+\beta^T)dp_0 - \frac{\beta^t(1-\beta)}{p}\sum_{k=1}^{T-1}dp_k. \end{aligned}$$

Finally, assuming dividends are constant, and using these computations, together with

$dQ_k = pdq_k + qdp_k$, we may write the demand for trees as

$$dq_0 = \theta_0(T)dq_{-1} + \theta_\star(T)dp_{-1} + \theta_1(T)dp_0 + \theta_2(T)dq_T + \theta_3(T)\sum_{k=1}^{T-1} dp_k + \theta_4(T)dp_T,$$

where

$$\begin{array}{rclcl} \theta_0(T) & = & \phi_0(T) & = & R\left(\frac{\beta(1-\beta^T)}{1-\beta^{T+1}}\right) \\ \theta_\star(T) & = & \frac{\phi_0(T)q}{p} - \frac{\phi_1(T)}{\beta p^2} & = & 0 \\ \theta_1(T) & = & -\frac{q}{p} + \frac{\phi_1(T)}{p^2} - \frac{\phi_3(T)}{p^2}(\sigma - 1 + \beta^T) & = & -\frac{(1-\beta)q}{(1-\beta^{T+1})p\sigma}(1-\beta^T) \\ \theta_2(T) & = & \phi_2(T) & = & \frac{(1-\beta)\beta^T}{1-\beta^{T+1}} \\ \theta_3(T) & = & -\frac{(1-\beta)\beta^T}{p^2}\phi_3(T) & = & \frac{(1-\beta)^2\beta^T}{1-\beta^{T+1}}\frac{q}{p\sigma} \\ \theta_4(T) & = & \phi_2(T)\frac{q}{p} + \frac{\phi_3}{p^2}((\sigma-1)\beta^T + \beta^{T+1}) & = & \theta_3(T) \end{array}.$$

The result follows. ■

Because Lemma 1 might be viewed as somewhat unexpected, in that it demonstrates that demand depends on average expected price rather than on the particulars of price expectations at a given forecast, we develop the intuition in more detail here. We begin with a distinct short proof that when $dp_0 = 0$, time zero consumption demand, dc_0, depends only on the sum of future prices. To this end, set $dq_{-1} = dp_0 = 0$, and let dq_t be given. The linearized budget constraints yield

$$\begin{array}{rcl} dc_0 + pdq_0 + qdp_0 = (p+y)dq_{-1} + qdp_0, & \text{or} & dc_0 = -pdq_0 \\ dc_1 + pdq_1 + qdp_1 = (p+y)dq_0 + qdp_1, & \text{or} & \beta dc_1 = pdq_0 - \beta pdq_1 \\ dc_2 + pdq_2 + qdp_2 = (p+y)dq_1 + qdp_2, & \text{or} & \beta^2 dc_2 = pdq_1 - \beta^2 pdq_2 \\ \vdots & & \vdots \\ dc_t + pdq_t + qdp_t = (p+y)dq_{t-1} + qdp_t, & \text{or} & \beta^t dc_t = pdq_{t-1} - \beta^t pdq_t. \end{array}$$

Summing, we obtain

$$\sum_{n=0}^{t} \beta^n dc_n = -\beta^t pdq_t. \tag{A.5}$$

The agent's FOC may be written $p_n u'(c_n) = \beta(p_{n+1}+y)u'(c_{n+1})$, which linearizes as

$$dc_{n+1} = dc_n + \psi(\beta dp_{n+1} - dp_n) \equiv dc_n + \psi \Delta p_{n+1},$$

where $\psi = (\sigma\beta)^{-1} q(1-\beta)$ and $\Delta p_{n+1} \equiv \beta dp_{n+1} - dp_n$. Backward iteration yields $dc_n = dc_0 + \psi \sum_{m=1}^{n} \Delta p_m$, which may be imposed into (A.5) to obtain

$$\sum_{n=0}^{t} \beta^n dc_0 + \psi \sum_{n=1}^{t} \beta^n \sum_{m=1}^{n} \Delta p_m = -\beta^t p dq_t. \tag{A.6}$$

Now a simple claim:

<u>Claim</u>. $\sum_{n=1}^{t} \beta^n \sum_{m=1}^{n} \Delta p_m = \beta^{t+1} \sum_{n=1}^{t} dp_n$.

The argument is by induction. For $t = 1$, use $dp_0 = 0$ to get the equality. Now assume it holds for $t-1$. Then

$$\begin{aligned}
\sum_{n=1}^{t} \beta^n \sum_{m=1}^{n} \Delta p_m &= \sum_{n=1}^{t-1} \beta^n \sum_{m=1}^{n} \Delta p_m + \beta^t \sum_{m=1}^{t} \Delta p_m \\
&= \beta^t \sum_{n=1}^{t-1} dp_n + \beta^t \sum_{m=1}^{t} \Delta p_m \\
&= \beta^t \sum_{n=1}^{t-1} dp_n + \beta^t \sum_{m=1}^{t} \beta dp_m - \beta^t \sum_{m=1}^{t} dp_{m-1} = \beta^{t+1} \sum_{m=1}^{t} \beta dp_m,
\end{aligned}$$

where the second equality applies the induction hypothesis.

Combining this claim with equation (A.6) demonstrates that when $dp_0 = 0$, time zero consumption demand, dc_0, depends only on $\sum_{n=1}^{t} dp_n$, completing our short proof.

We turn now to intuition for Lemma 1 by establishing that ${}^{\partial dc_0}/_{\partial dp_m}$ is independent of m for $1 \le m \le T$. First, note that model's decision-making problem is often written using the more common language of returns, $R_k = p_{k-1}^{-1}(p_k + y)$, and it can shown that the agent's decision rules depend on the present value of expected future returns. To link this dependence with the proposition, and assuming perfect foresight for convenience, note that to first order, $dR_k = (\beta p)^{-1}(\beta dp_k - dp_{k-1})$. It follows that ${}^{\partial}/_{\partial dp_m} \sum_{k=1}^{\infty} \beta^k dR_k = 0$. Thus, in the infinite horizon case we have $\partial c_t / \partial p_{t+m} = 0$ and $\partial q_t / \partial p_{t+m} = 0$; further, in the finite horizon case, it can be shown that $\partial c_t / \partial p_{t+m}$ and $\partial q_t / \partial p_{t+m}$ are independent of m for $1 \le m \le T$. We conclude that the average price path is a sufficient statistic for dc_t and dq_t, exactly in line with Lemma 1.

More carefully,

$$\frac{\partial dR_k}{\partial dp_m} = \begin{cases} p^{-1}dp_m & \text{if } k = m \\ -(\beta p)^{-1}dp_m & \text{if } k = m+1 \\ 0 & \text{otherwise} \end{cases}$$

Thus for $m < T$ we have $\partial/\partial dp_m \sum_{k=0}^{T} \beta^k dR_k = 0$, and we note that this computation holds for $T = \infty$.

Next, recall it was assumed that $dq_{-1} = dp_{-1} = 0$. It follows that $R_0 Q_{-1}$ linearizes as qdp_0. Thus we may write equation (A.3) as

$$\sum_{k=0}^{T} \beta^k dc_k = qdp_0 - \beta^T pdq_T - \beta^T qdp_T + Q \sum_{k=0}^{T} \beta^k dR_k. \tag{A.7}$$

Next, we claim that

$$dc_0 = \frac{1-\beta}{1-\beta^{T+1}} \left(qdp_0 - \beta^T pdq_T - \beta^T qdp_T + \frac{Q(\sigma-1)}{\sigma} \sum_{k=1}^{T} \beta^k dR_k + \frac{Q}{\sigma} \beta^{T+1} \sum_{k=1}^{T} dR_k \right). \tag{A.8}$$

To see this, combine (A.2) and (A.7) to get

$$\sum_{k=0}^{T} \beta^k \left(dc_0 + \frac{(1-\beta)Q}{\sigma} \sum_{m=1}^{k} dR_m \right) = q_{-1}dp_0 - \beta^T dQ_T + Q \sum_{k=1}^{T} \beta^k dR_k,$$

or

$$\left(\frac{1-\beta^{T+1}}{1-\beta} \right) dc_0 \quad = \quad qdp_0 - \beta^T dQ_T + Q \sum_{k=1}^{T} \beta^k dR_k - \frac{(1-\beta)Q}{\sigma} \sum_{k=1}^{T} \beta^k \sum_{m=1}^{k} dR_m.$$

Now notice

$$\sum_{k=1}^{T} \beta^k \sum_{m=1}^{k} dR_m = \sum_{k=1}^{T} \left(\frac{\beta^k - \beta^{T+1}}{1-\beta} \right) dR_k,$$

from which equation (A.8) follows. Using (A.8), we find

$$\frac{\partial dc_0}{\partial dp_T} = -\beta^T q + \frac{Q(\sigma-1)}{\sigma p} \beta^T + \frac{Q}{\sigma p} \beta^{T+1} = \beta^T \frac{Q}{\sigma p} (\beta - 1). \tag{A.9}$$

For $1 \leq m < T$, and noting our above result that $\partial/\partial dp_m \sum_{k=1}^{T} \beta^k dR_k = 0$, we may use equation (A.8) to compute

$$\frac{\partial dc_0}{\partial dp_m} = \frac{\partial}{\partial dp_m} \frac{Q}{\sigma} \beta^{T+1} \sum_{k=1}^{T} dR_k = \beta^T \frac{Q}{\sigma p} (\beta - 1),$$

which is exactly the same value as was computed for ${}^{\partial dc_0}\!/\!_{\partial dp_T}$ in equation (A.9). It follows that ${}^{\partial dc_0}\!/\!_{\partial dp_m}$ is independent of m for $1 \leq m \leq T$, whence the average expected price path is a sufficient statistic for the determination of dc_0, and hence for asset demand dq_0.

A.2.1 Proof of Proposition 2.1.

Let α_i be the proportion of agents of type i, for $i = 1, \ldots, I$, and let

$$\alpha = \{\alpha_1, \ldots, \alpha_I\} \text{ and } \mathscr{T} = \{T_1, \ldots, T_I\}.$$

Since we allow agents of different types to have planning horizons of the same length, we may assume agents of the same type hold the same forecasts. By Lemma 1, the demand schedule for an agent of type i is given by

$$dq_{it} = g(T_i)\, dq_{it-1} - \phi g(T_i)\, dp_t + T_i^{-1} h(T_i)\, dq^e_{i,t+T} + \phi h(T_i) \left(\frac{1}{T_i} \sum_{k=1}^{T_i} dp^e_{i,t+k} \right). \quad \text{(A.10)}$$

Thus, in this framework, heterogeneous wealth and expectations lead to heterogeneous demand schedules, providing a motive for trade and inducing price dynamics.

As discussed in Section A.1, we assume $dq^e_{it+T} = dq_{it-1}$, which implies that the demand schedule of an agent of type i reduces to

$$dq_{it} = dq_{it-1} - \phi g(T_i) dp_t + \phi h(T_i) d\bar{p}^e_{it}(T_i), \quad \text{(A.11)}$$

where $d\bar{p}^e_{it}(T_i)$ denotes the expected average price of an agent of type i with planning horizon T_i. Market clearing in each period implies $\sum_i \alpha_i dq_{it} = \sum_i \alpha_i dq_{it-1} = 0$, $\forall t$, which uniquely determines the price p_t:

$$dp_t = \sum_i \xi(\alpha, \mathscr{T}, i) d\bar{p}^e_{it}(T_i), \text{ where } \xi(\alpha, \mathscr{T}, i) \equiv \frac{\alpha_i h(T_i)}{\sum_j \alpha_j g(T_j)}. \quad \text{(A.12)}$$

Thus the time t price only depends on the agents' forecasts of the *average* price of chickens over their planning horizon, i.e. $\{d\bar{p}^e_{it}(T_i)\}_{i=1}^{I}$. The asset-pricing model with heterogeneous agents is therefore an *expectational feedback* system, in which the perfect foresight steady-state price is exactly self-fulfilling and is unique.

It remains to show that $\xi(\alpha,T) \equiv \sum_i \xi(\alpha,\mathscr{T},i) \in (0,1)$. That $\xi(\alpha,\mathscr{T},i) > 0$, and hence $\xi(\alpha,T) > 0$, follows from construction. The argument is completed by observing

$$\begin{aligned}\xi(\alpha,T) &= \frac{(1-\beta)\sum_i \left(\frac{\alpha_i T_i \beta^{T_i}}{1-\beta^{T_i+1}}\right)}{\sum_j \left(\frac{\alpha_j(1-\beta^{T_j})}{1-\beta^{T_j+1}}\right)} = \frac{\sum_i \left(\frac{\alpha_i T_i \beta^{T_i}}{1-\beta^{T_i+1}}\right)}{\sum_j \left(\frac{\alpha_j \left(\frac{1-\beta^{T_j}}{1-\beta}\right)}{1-\beta^{T_j+1}}\right)} \\ &= \frac{\sum_i \left(\frac{\alpha_i T_i \beta^{T_i}}{1-\beta^{T_i+1}}\right)}{\sum_j \left(\frac{\alpha_j \left(\sum_{k=0}^{T_j-1} \beta^k\right)}{1-\beta^{T_j+1}}\right)} < \frac{\sum_i \left(\frac{\alpha_i T_i \beta^{T_i}}{1-\beta^{T_i+1}}\right)}{\sum_j \left(\frac{\alpha_j \left(\sum_{k=0}^{T_j-1} \beta^{T_j}\right)}{1-\beta^{T_j+1}}\right)} = 1. \blacksquare\end{aligned}$$

A.2.2 Proof of Proposition 2.2.

To establish item 1, we allow T to take any positive real value. It suffices to show that

$$f(x) = \log \xi(x) - \log(1-\beta) = \log x + x \log \beta - \log(1-\beta^x)$$

is decreasing in x for $x > 0$. Notice that

$$f'(x) = \frac{1}{x} + \frac{\log \beta}{1-\beta^x},$$

hence for $x > 0$,

$$f'(x) \leq 0 \Longleftrightarrow \frac{1}{\log \beta^{-1}} \leq \frac{x}{1-\beta^x} \equiv h(x).$$

Using L'Hopital's rule, we find that $h(0) = 1/\log \beta^{-1}$; thus it suffices to show that $h'(x) > 0$ for $x > 0$. Now compute

$$h'(x) = \frac{1-\beta^x(1+x\log\beta^{-1})}{(1-\beta^x)^2}.$$

It follows that for $x > 0$,

$$h'(x) > 0 \Longleftrightarrow h_1(x) \equiv \frac{1-\beta^x}{\beta^x} > x \log \beta^{-1} \equiv h_2(x).$$

Since $h_1(0) = h_2(0)$ and

$$h_1'(x) = \beta^{-x} \log \beta^{-1} > \log \beta^{-1} = h_2'(x),$$

the result follows.

Turning to item 2, let $g(T_i) = (1-\beta^{T_i+1})^{-1}(1-\beta^{T_i})$. Assume $T_1 < T_2$, and, abusing notation somewhat, write

$$\xi(\alpha, T) = \frac{\alpha \xi(T_1) g(T_1) + (1-\alpha)\xi(T_2) g(T_2)}{\alpha g(T_1) + (1-\alpha) g(T_2)},$$

where we recall that

$$\xi(T) = (1-\beta)\frac{T\beta^T}{1-\beta^{T+1}}.$$

It suffices to show $\xi_\alpha > 0$. But notice this holds if and only if

$$\begin{aligned} & (\alpha g(T_1) + (1-\alpha) g(T_2))(\xi(T_1) g(T_1) - \xi(T_2) g(T_2)) \\ > \quad & (\alpha \xi(T_1) g(T_1) + (1-\alpha)\xi(T_2) g(T_2))(g(T_1) - g(T_2)) \\ \iff & \\ & \alpha(\xi(T_1) - \xi(T_2)) > (1-\alpha)(\xi(T_2) - \xi(T_1)). \end{aligned}$$

The last inequality holds from item 1 above and the fact that $T_2 > T_1$. ■

A.3 Individual demand schedule dynamics

Without loss of generality, assume homogeneous planning horizons and omit index i. Denote the expected average price over the next T periods by $d\bar{p}_t^e(T)$:

$$d\bar{p}_t^e(T) \equiv \frac{1}{T}\sum_{k=1}^{T} dp_{t+k}^e.$$

Then demand of the agent may be written

$$\begin{aligned} dq_t &= dq_{t-1} - \phi g(T) dp_t + \phi h(T) d\bar{p}_t^e(T) \\ dc_t &= y dq_{t-1} + p\phi g(T) dp_t - p\phi h(T) d\bar{p}_t^e(T), \end{aligned}$$

where

$$\phi = \frac{(1-\beta)q}{p\sigma},\ g(T) = \frac{1-\beta^T}{1-\beta^{T+1}},\ \text{and}\ h(T) = \frac{(1-\beta)T\beta^T}{1-\beta^{T+1}}.$$

It follows that the agent's demand for chickens is decreasing in current price and increasing in expected average price.

We now consider the agent's time t plan for holding chickens over the planning period t to $t+T$. Assuming that, at time t, the agent believes that her expected average price over the time period $t+k$ to $t+T$ will be $dp_t^e(T)$ for each $k \in \{1,\ldots,T-1\}$, we may compute the plans for chicken holdings as

$$dq_{t+k} = dq_{t+k-1} - \phi(g(T-k) - h(T-k))d\bar{p}_t^e(T).$$

Letting $\Delta_T(j) = g(T-j) - h(T-j)$, it follows that

$$dq_{t+k} = dq_{t-1} - \phi g(T)dp_t + \phi h(T)d\bar{p}_t^e(T) - \phi\left(\sum_{j=1}^{k}\Delta_T(j)\right)d\bar{p}_t^e(T) \quad \text{(A.13)}$$

$$\begin{aligned} dc_{t+k} &= ydq_{t-1} - y\phi g(T)dp_t + y\phi h(T)d\bar{p}_t^e(T) \\ &\quad -\phi y\left(\sum_{j=1}^{k-1}\Delta_T(j)\right)d\bar{p}_t^e(T) + p\phi\Delta_T(k)d\bar{p}_t^e(T). \end{aligned} \quad \text{(A.14)}$$

Written differently, we have

$$\Delta dq_t = -\phi(g(T)dp_t - h(T)d\bar{p}_t^e(T)) \quad \text{(A.15)}$$

$$\Delta dq_{t+k} = -\phi\Delta_T(k)d\bar{p}_t^e(T)). \quad \text{(A.16)}$$

The formulae identifying the changes in consumption are less revealing.

Now observe that $\Delta_T(k) > 0$. Indeed, letting $n = T-k$, we have

$$\begin{aligned} \Delta_T(k) &= \frac{1-\beta^n-(1-\beta)n\beta^n}{1-\beta^{n+1}} = (1-\beta)\left(\frac{\frac{1-\beta^n}{1-\beta} - n\beta^n}{1-\beta^{n+1}}\right) \\ &= (1-\beta)\left(\frac{\sum_{i=0}^{n-1}\beta^i - n\beta^n}{1-\beta^{n+1}}\right) = (1-\beta)\left(\frac{\sum_{i=0}^{n-1}(\beta^i-\beta^n)}{1-\beta^{n+1}}\right) > 0. \end{aligned}$$

We may now consider the following thought experiments. Here we assume all variables are at steady state (i.e. zero in differential form) unless otherwise stated. All references to periods $t+k$ concern "plans," not realizations, and it is assumed that $k \in \{1, \ldots, T-1\}$.

1. **A rise in price.** If $dp_t > 0$, then by equations (A.15) and (A.16) chicken holdings are reduced in time t by $-\phi g(T) dp_t$ and the reduction is maintained throughout the period. Consumption rises in period t by $p\phi g(T) dp_t$ and is reduced in subsequent periods by $y\phi g(T) dp_t$. Intuitively, the rise in price today, together with change in expected future prices, lowers the return to holding chickens between today and tomorrow, causing the agent to substitute toward consumption today. After one period, the new, lower steady-state levels of consumption and chicken holdings are reached and maintained through the planning period.

2. **A rise in expected price.** If $d\bar{p}_t^e(T) > 0$, then by Equations (A.15) and (A.16), current chicken holdings rise by $\phi h(T) d\bar{p}_t^e(T)$ and then decline over time. Consumption falls in time t, rises in time $t+1$, and is otherwise more complicated. Notice that our assumption of random-walk expectations of future chicken holdings forces holdings back to the original steady state.

A.4 Proofs of Corollaries 1 and 2

Proof of Corollary 1. Here we provide the argument for the constant gain case. The decreasing gain case is somewhat more involved but ultimately turns on the same computations.

Stack agents' expectations into the vector $d\bar{p}_t^e$, and let

$$\hat{\xi} = \begin{pmatrix} \xi(\alpha, \mathscr{T}, 1) & \cdots & \xi(\alpha, \mathscr{T}, N) \\ \xi(\alpha, \mathscr{T}, 1) & \cdots & \xi(\alpha, \mathscr{T}, N) \\ \vdots & \ddots & \vdots \\ \xi(\alpha, \mathscr{T}, 1) & \cdots & \xi(\alpha, \mathscr{T}, N) \end{pmatrix}.$$

Observe that $\hat{\xi}$ has an eigenvalue of zero with multiplicity $N-1$, and the remaining eigenvalue given by $\operatorname{tr}\hat{\xi} = \sum_i \xi(\alpha, \mathscr{T}, i)$, which, by Proposition 2.2, is contained in $(0,1)$.

The recursive algorithm characterizing the beliefs dynamics of agent i may be written,

$$d\bar{p}_t^e(i, T_i) = d\bar{p}_{t-1}^e(i, T_i) + \gamma \left(\sum_i \xi(\alpha, \mathscr{T}, i) d\bar{p}_{t-1}^e(i, T_i) - d\bar{p}_{t-1}^e(i, T_i) \right),$$

or, in stacked form,

$$d\bar{p}_t^e = \left((1-\gamma)I_N + \gamma\hat{\xi}\right) d\bar{p}_{t-1}^e. \tag{A.17}$$

Stability requires that the eigenvalues of $(1-\gamma)I_N + \gamma\hat{\xi}$ be strictly less than one in modulus, and this is immediately implied by our above observation about the eigenvalues of $\hat{\xi}$. Via Eq. (A.12), convergence of expected price deviations to zero implies convergence of the realized price deviation to zero. ■

Proof of Corollary 2. The matrix $(1-\gamma)I_N + \gamma\hat{\xi}$ has, as eigenvalues, $N-1$ copies of $1-\gamma$ and

$$\zeta = 1-\gamma+\gamma\sum_i \xi(\alpha,\mathscr{T},i).$$

Denote by S the corresponding matrix of eigen vectors and change coordinates: $z_t = S^{-1}d\bar{p}_t^e$. The dynamics (A.17) becomes the decoupled system $z_t = \Lambda z_{t-1}$. Denote by z_t^ζ the component of z_t corresponding to the eigenvalue ζ. With the aid of a computer algebra system, it is straightforward to show that

$$z_t^\zeta = \left(\sum_i \xi(\alpha,\mathscr{T},i)\right)^{-1} \sum_i \xi(\alpha,\mathscr{T},i) d\bar{p}_t^e(i,T_i) = \xi(\alpha,\mathscr{T})^{-1} dp_t.$$

It follows that ${}^{dp_t}/{}_{dp_{t-1}} = {}^{z_t^\zeta}/{}_{z_{t-1}^\zeta} = \zeta$. The argument is completed by noting that ζ is decreasing in T_i. ■

B Additional figures

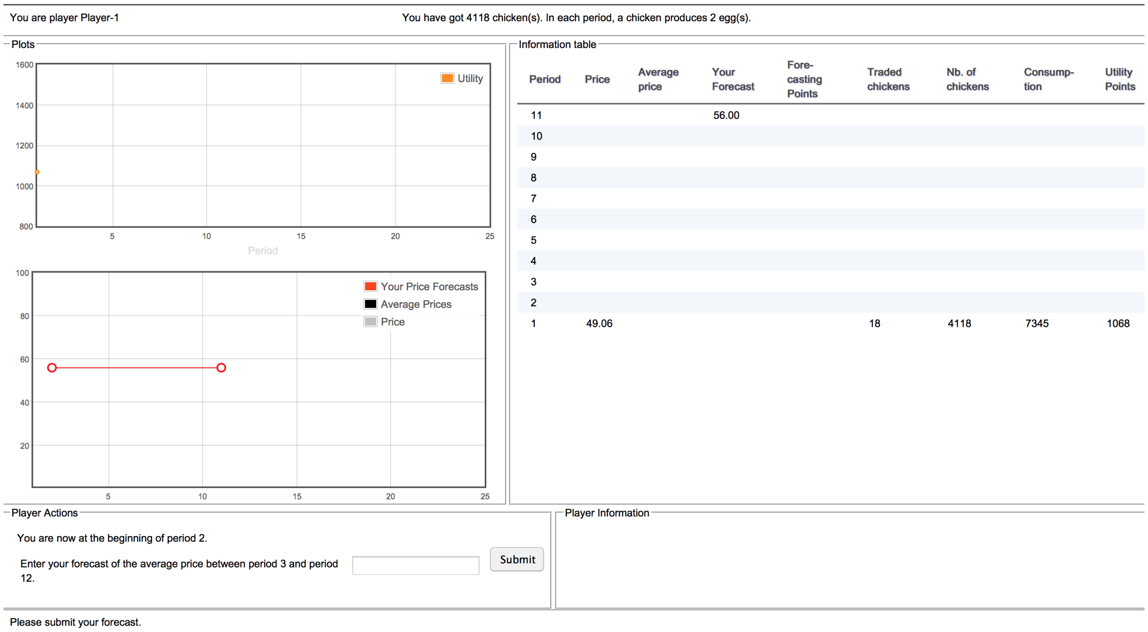


Figure 1: Screen shot of the experimental interface for a long-horizon participant

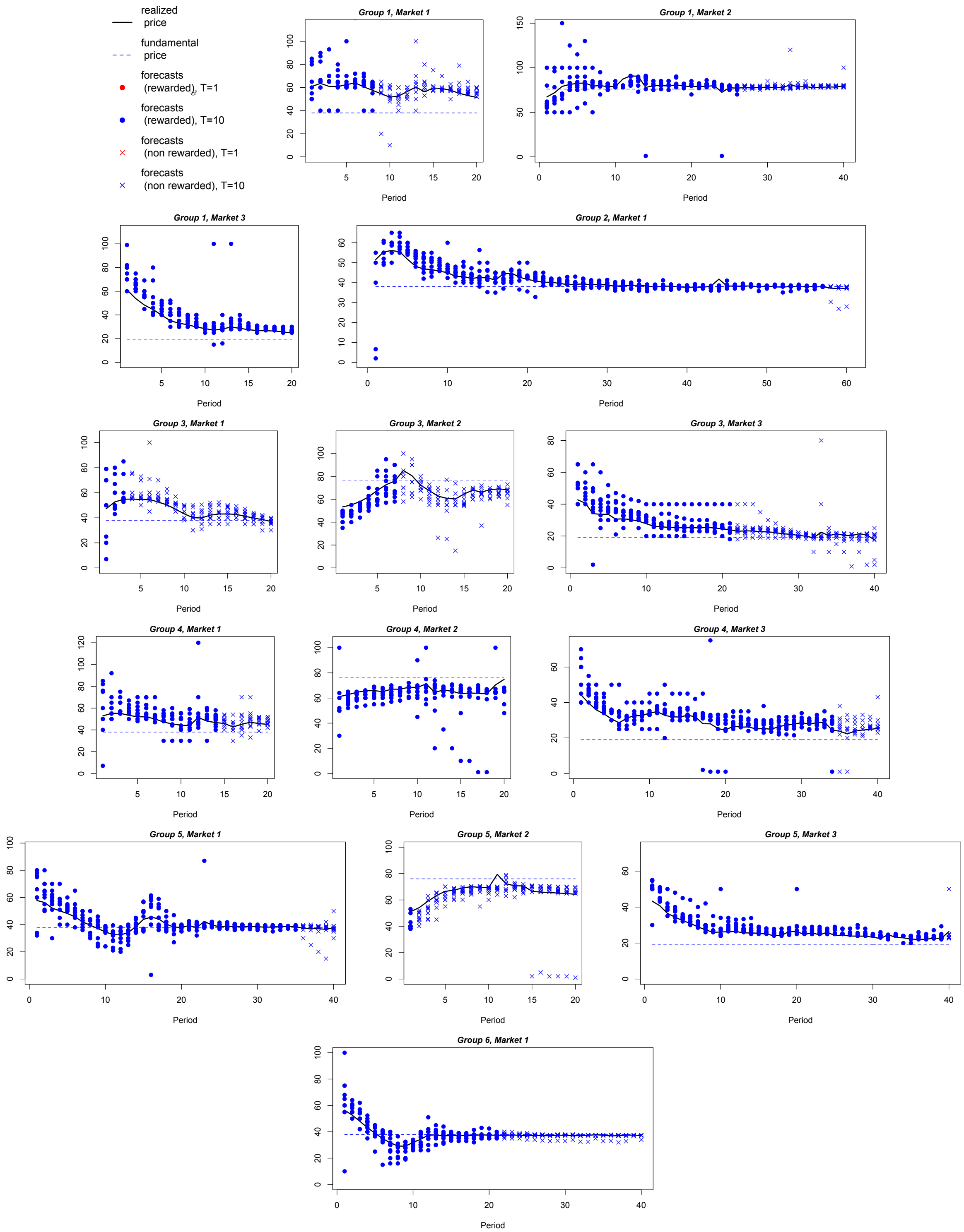


Figure 2: Prices and participants' forecasts in Treatment L: 100% $T = 10$ (6 groups)

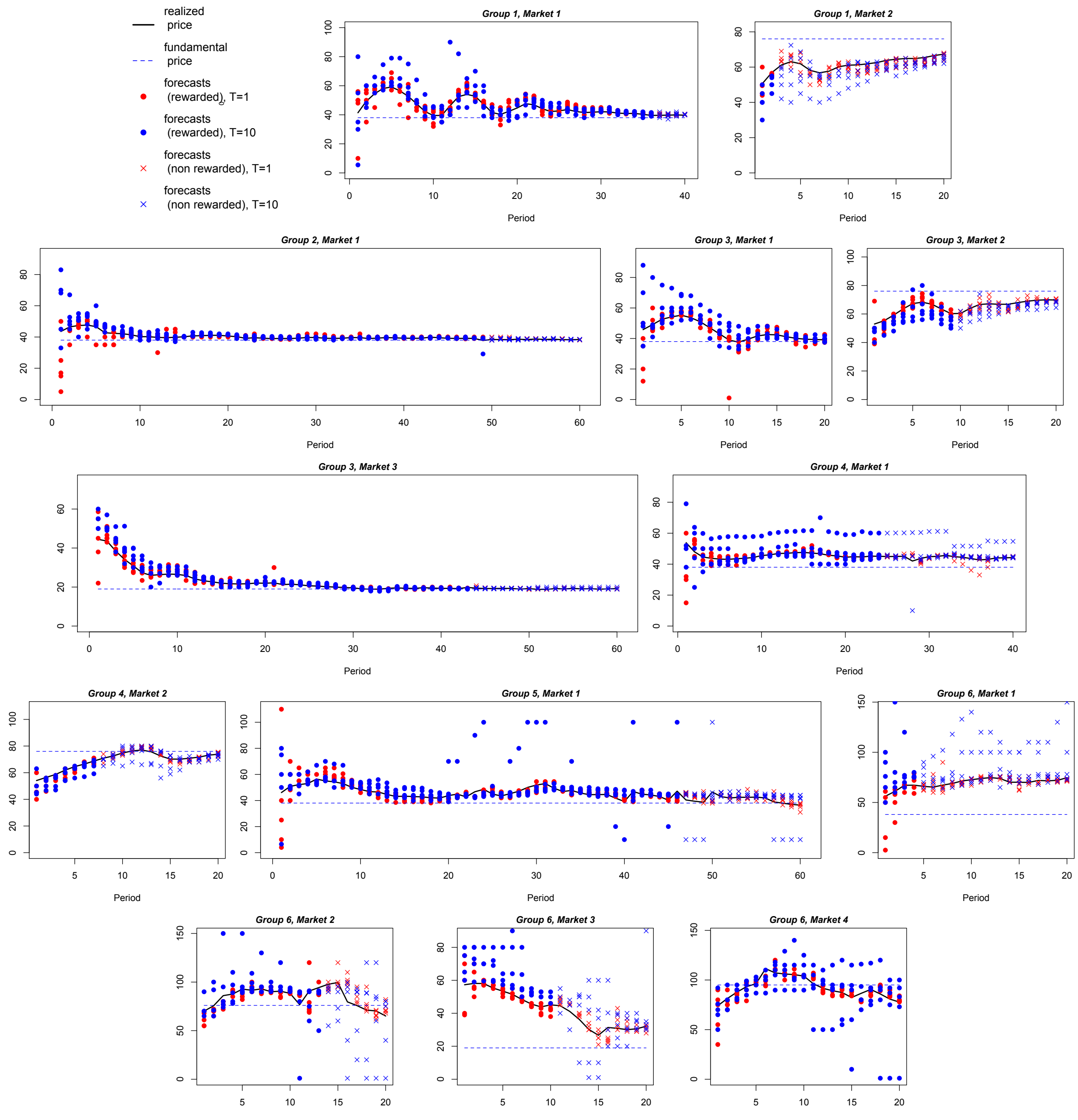


Figure 3: Prices and participants' forecasts in Treatment M50: 50% $T = 1$/50% $T = 10$ (6 groups)

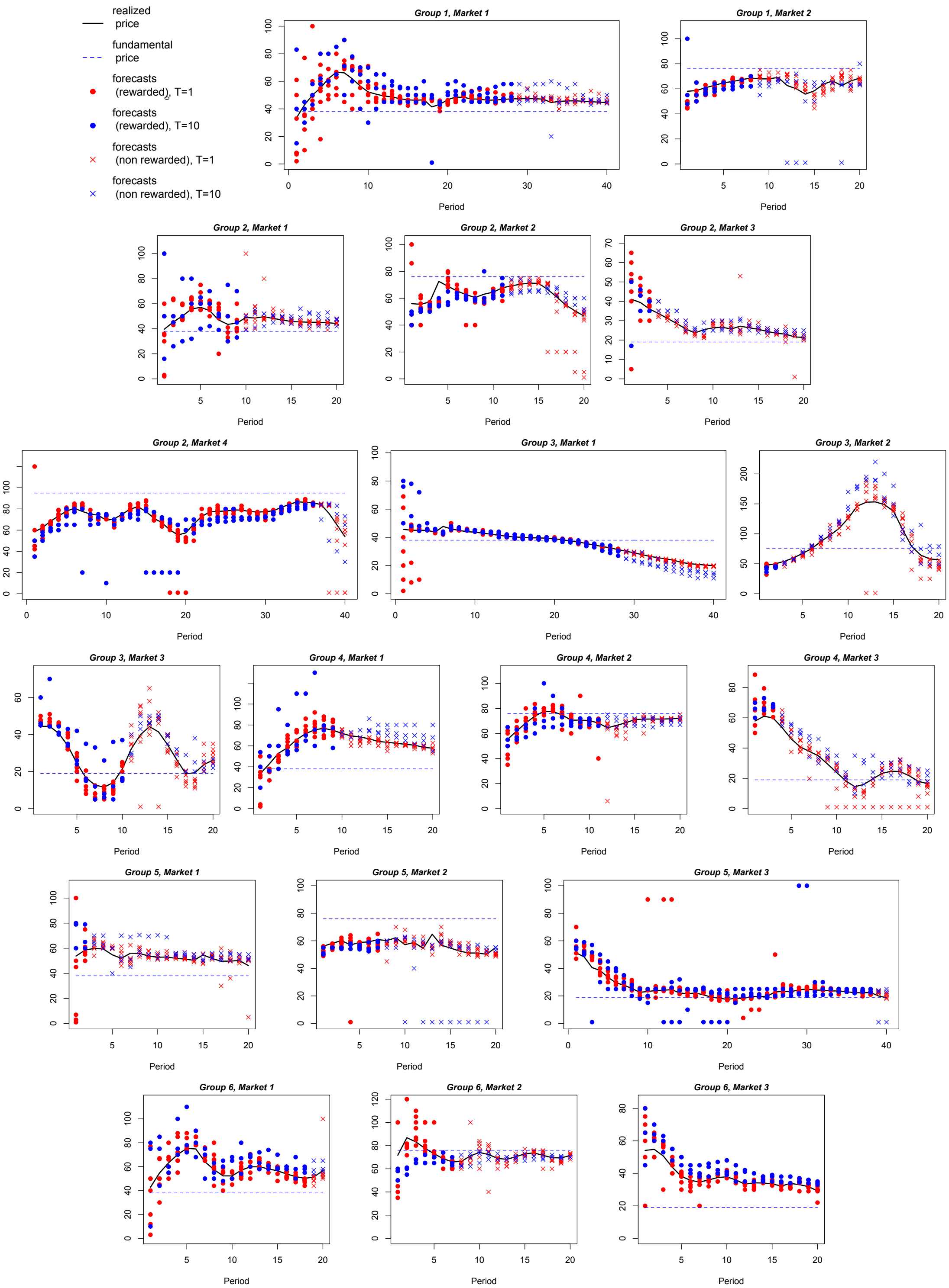


Figure 4: Prices and participants' forecasts in Treatment `M70`: 70% $T = 1$/30% $T = 10$

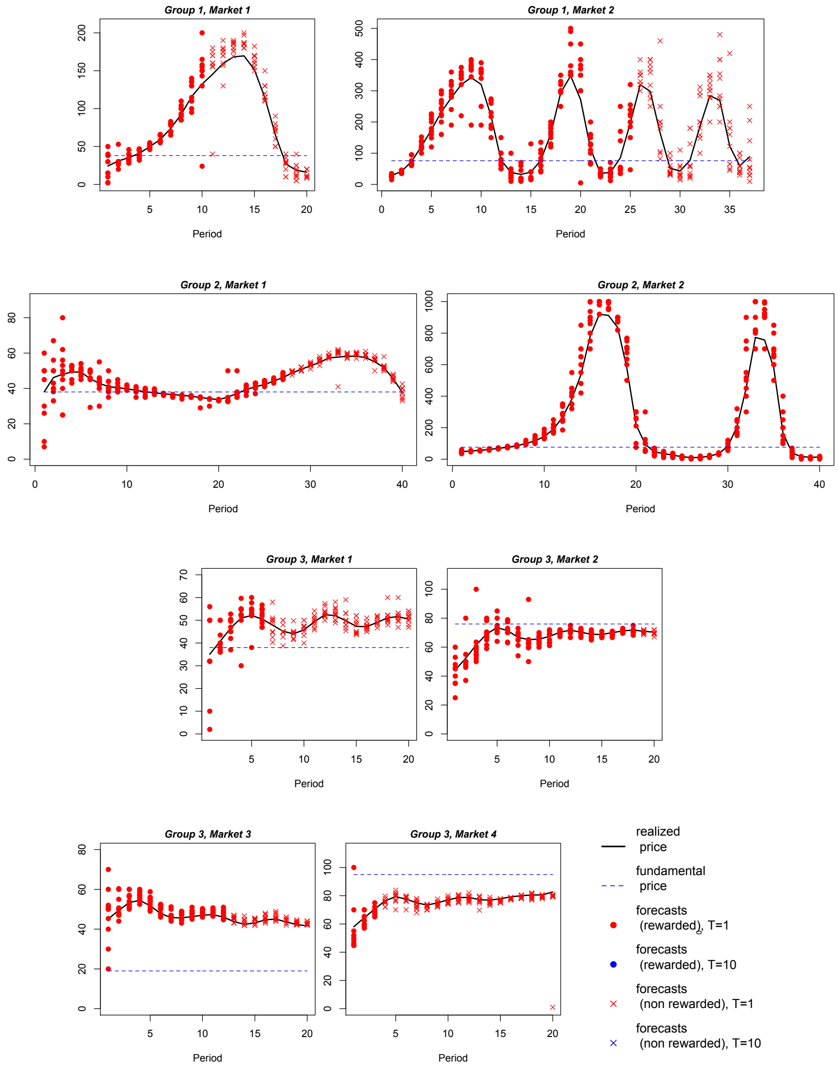


Figure 5: Prices and participants' forecasts in Treatment S: 100% $T = 1$ (groups 1 - 3)

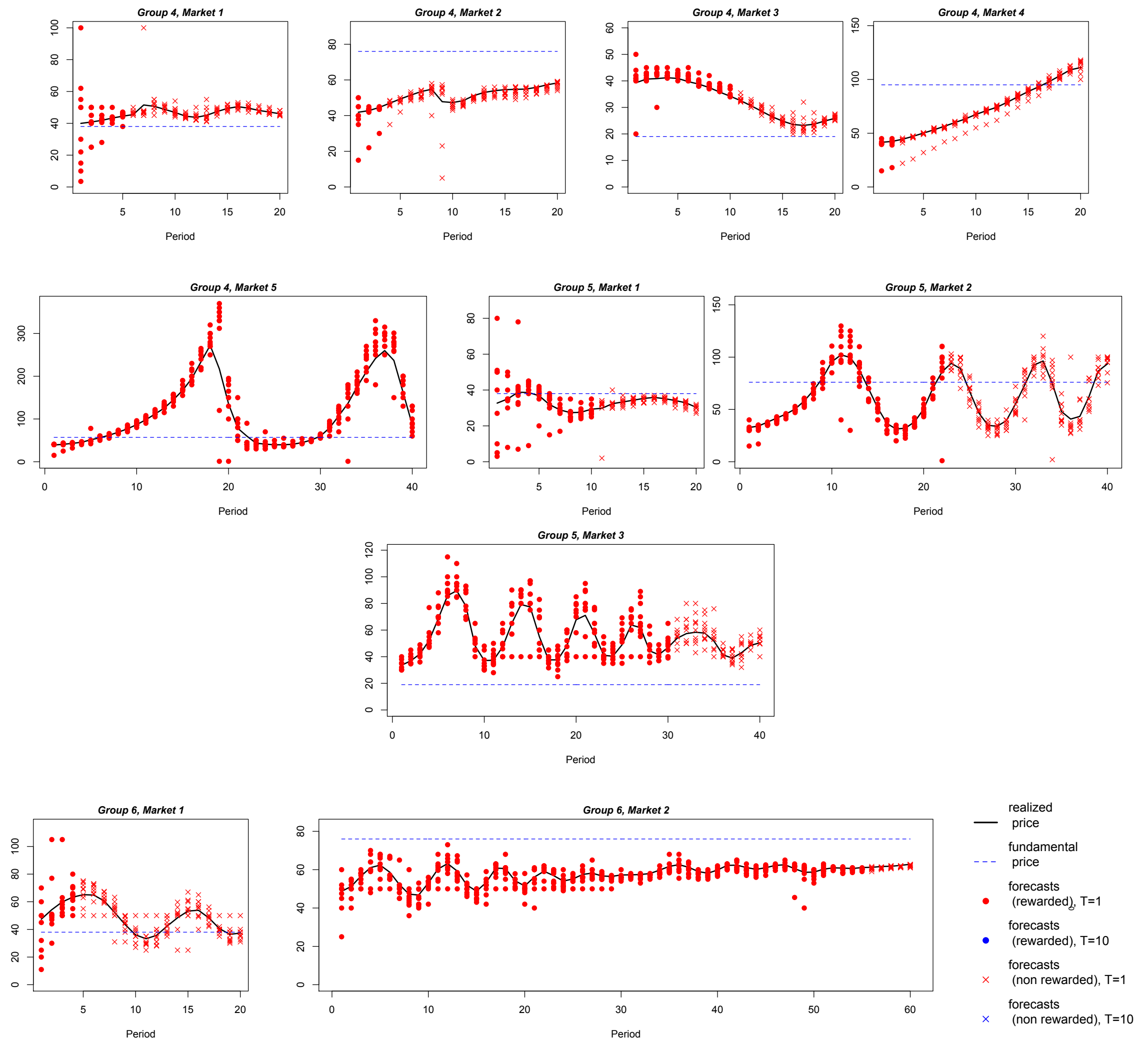


Figure 6: Prices and participants' forecasts in Treatment S: 100% $T = 1$ (groups 4 - 6)

C Test of the equilibration hypothesis: estimation outcomes of Equation (4)

For each treatment, we report below the estimated coefficients $\{\hat{b}_{1,m}, \hat{b}_{2,m}\}$ in Equation (4) for each market $m_{i,m}$ (subscript i corresponds to the group number and subscript m to the number of the market). Standard deviations are reported between brackets. We highlight in bold the markets that exhibit weak convergence, and denote with a star those exhibiting strong convergence.

Tr. `S` $m_{1,1}:\left\{\underset{(0.464)}{-1.012},\underset{(0.449)}{1.715}\right\}$; $m_{1,2}:\left\{\underset{(0.365)}{-0.565},\underset{(0.224)}{1.321}\right\}$; $m^*_{2,1}:\left\{\underset{(0.104)}{0.040},\underset{(0.103)}{0.183}\right\}$; $m_{2,2}:\left\{\underset{(0.958)}{-1.821},\underset{(0.903)}{2.714}\right\}$; $m_{3,1}:\left\{\underset{(0.015)}{-0.069},\underset{(0.011)}{0.335}\right\}$; $\mathbf{m_{3,2}}:\left\{\underset{(0.009)}{-0.433},\underset{(0.005)}{-0.048}\right\}$; $m_{3,3}:\left\{\underset{(0.122)}{1.646},\underset{(0.084)}{1.393}\right\}$; $\mathbf{m_{3,4}}:\left\{\underset{(0.007)}{-0.408},\underset{(0.006)}{-0.155}\right\}$; $m_{4,1}:\left\{\underset{(0.018)}{-0.001},\underset{(0.011)}{0.265}\right\}$; $\mathbf{m_{4,2}}:\left\{\underset{(0.021)}{-0.500},\underset{(0.017)}{-0.290}\right\}$; $\mathbf{m_{4,3}}:\left\{\underset{(0.217)}{1.469},\underset{(0.180)}{0.554}\right\}$; $\mathbf{m_{4,4}}^*:\left\{\underset{(0.130)}{-0.805},\underset{(0.111)}{-0.121}\right\}$; $m_{4,5}:\left\{\underset{(0.506)}{-1.224},\underset{(0.354)}{1.220}\right\}$; $m_{5,1}:\left\{\underset{(0.028)}{-0.076},\underset{(0.019)}{-0.143}\right\}$; $\mathbf{m_{5,2}}:\left\{\underset{(0.064)}{-0.693},\underset{(0.047)}{-0.126}\right\}$; $m_{5,3}:\left\{\underset{(0.335)}{1.068},\underset{(0.162)}{1.910}\right\}$; $m_{6,1}:\left\{\underset{(0.134)}{0.527},\underset{(0.099)}{0.232}\right\}$; $\mathbf{m_{6,2}}:\left\{\underset{(0.026)}{-0.384},\underset{(0.014)}{-0.223}\right\}$.

Observations: 518; Adj. $R^2 = 0.381$; F Statistic: 9.849 (df = 36; 482)

Tr. `M70` $m_{1,1}:\left\{\underset{(0.121)}{0.137},\underset{(0.064)}{0.295}\right\}$; $\mathbf{m_{1,2}}:\left\{\underset{(0.008)}{-0.245},\underset{(0.009)}{-0.142}\right\}$; $m_{2,1}:\left\{\underset{(0.049)}{0.154},\underset{(0.035)}{0.272}\right\}$; $\mathbf{m_{2,2}}:\left\{\underset{(0.027)}{-0.257},\underset{(0.025)}{-0.156}\right\}$; $\mathbf{m_{2,3}}:\left\{\underset{(0.072)}{1.410},\underset{(0.044)}{0.256}\right\}$; $\mathbf{m_{2,4}}:\left\{\underset{(0.017)}{-0.391},\underset{(0.014)}{-0.202}\right\}$; $\mathbf{m_{3,1}}^*:\left\{\underset{(0.161)}{0.493},\underset{(0.113)}{-0.127}\right\}$; $m_{3,2}:\left\{\underset{(0.103)}{-0.655},\underset{(0.102)}{0.431}\right\}$; $\mathbf{m_{3,3}}:\left\{\underset{(0.088)}{1.497},\underset{(0.093)}{0.286}\right\}$; $m_{4,1}:\left\{\underset{(0.067)}{-0.147},\underset{(0.063)}{0.831}\right\}$; $\mathbf{m_{4,2}}:\left\{\underset{(0.016)}{-0.248},\underset{(0.013)}{-0.043}\right\}$; $\mathbf{m_{4,3}}^*:\left\{\underset{(0.297)}{2.993},\underset{(0.191)}{0.184}\right\}$; $\mathbf{m_{5,1}}:\left\{\underset{(0.043)}{0.542},\underset{(0.030)}{0.371}\right\}$; $m_{5,2}:\left\{\underset{(0.020)}{-0.227},\underset{(0.017)}{-0.255}\right\}$; $\mathbf{m_{5,3}}:\left\{\underset{(0.110)}{2.140},\underset{(0.039)}{0.088}\right\}$; $m_{6,1}:\left\{\underset{(0.099)}{0.348},\underset{(0.072)}{0.569}\right\}$; $m_{6,2}:\left\{\underset{(0.023)}{0.047},\underset{(0.009)}{-0.069}\right\}$; $\mathbf{m_{6,3}}:\left\{\underset{(0.095)}{2.210},\underset{(0.052)}{0.716}\right\}$.

Observations: 441; Adj. $R^2 = 0.783$; F Statistic: 45.21 (df = 36; 405)

Tr. `M50` $m_{1,1}: \left\{ \underset{(0.108)}{0.373}, \underset{(0.055)}{0.163} \right\}$; $\mathbf{m_{1,2}}: \left\{ \underset{(0.012)}{-0.341}, \underset{(0.012)}{-0.157} \right\}$; $\mathbf{m_{2,1}}: \left\{ \underset{(0.045)}{0.295}, \underset{(0.012)}{0.035} \right\}$; $\mathbf{m_{3,1}}^*: \left\{ \underset{(0.080)}{0.391}, \underset{(0.075)}{0.128} \right\}$; $\mathbf{m_{3,2}}: \left\{ \underset{(0.012)}{-0.337}, \underset{(0.010)}{-0.106} \right\}$; $\mathbf{m_{3,3}}^*: \left\{ \underset{(0.140)}{1.846}, \underset{(0.043)}{0.029} \right\}$; $\mathbf{m_{4,1}}: \left\{ \underset{(0.019)}{0.368}, \underset{(0.010)}{0.166} \right\}$; $\mathbf{m_{4,2}}: \left\{ \underset{(0.022)}{-0.361}, \underset{(0.013)}{-0.033} \right\}$; $\mathbf{m_{5,1}}: \left\{ \underset{(0.092)}{0.447}, \underset{(0.035)}{0.170} \right\}$; $m_{6,1}: \left\{ \underset{(0.019)}{0.426}, \underset{(0.014)}{0.911} \right\}$; $m_{6,2}: \left\{ \underset{(0.052)}{-0.026}, \underset{(0.046)}{0.139} \right\}$; $\mathbf{m_{6,3}}: \left\{ \underset{(0.265)}{2.633}, \underset{(0.200)}{0.932} \right\}$; $\mathbf{m_{6,4}}^*: \left\{ \underset{(0.049)}{-0.176}, \underset{(0.044)}{-0.003} \right\}$.

Observations: 421; Adj. $R^2 = 0.887$; F Statistic: 128.3 (df = 26; 395)

Tr. `L` $\mathbf{m_{1,1}}: \left\{ \underset{(0.035)}{0.697}, \underset{(0.024)}{0.487} \right\}$; $m_{1,2}: \left\{ \underset{(0.026)}{-0.079}, \underset{(0.017)}{0.057} \right\}$; $\mathbf{m_{1,3}}: \left\{ \underset{(0.128)}{2.621}, \underset{(0.077)}{0.381} \right\}$; $\mathbf{m_{2,1}}^*: \left\{ \underset{(0.097)}{0.663}, \underset{(0.032)}{0.034} \right\}$; $\mathbf{m_{3,1}}^*: \left\{ \underset{(0.090)}{0.457}, \underset{(0.066)}{0.155} \right\}$; $\mathbf{m_{3,2}}: \left\{ \underset{(0.020)}{-0.325}, \underset{(0.020)}{-0.074} \right\}$; $\mathbf{m_{3,3}}^*: \left\{ \underset{(0.138)}{1.632}, \underset{(0.097)}{0.179} \right\}$; $\mathbf{m_{4,1}}: \left\{ \underset{(0.040)}{0.512}, \underset{(0.026)}{0.223} \right\}$; $\mathbf{m_{4,2}}: \left\{ \underset{(0.005)}{-0.205}, \underset{(0.005)}{-0.113} \right\}$; $\mathbf{m_{4,3}}: \left\{ \underset{(0.091)}{1.531}, \underset{(0.062)}{0.412} \right\}$; $\mathbf{m_{5,1}}^*: \left\{ \underset{(0.040)}{0.676}, \underset{(0.011)}{-0.007} \right\}$; $\mathbf{m_{5,2}}: \left\{ \underset{(0.015)}{-0.362}, \underset{(0.014)}{-0.077} \right\}$; $\mathbf{m_{5,3}}: \left\{ \underset{(0.086)}{1.579}, \underset{(0.036)}{0.249} \right\}$; $\mathbf{m_{5,3}}: \left\{ \underset{(0.041)}{0.522}, \underset{(0.025)}{-0.068} \right\}$.

Observations: 441; Adj. $R^2 = 0.910$; F Statistic: 160.8 (df = 28; 413)

D Instructions

D.1 Instructions for short-horizon forecasters

Welcome to our experiment! The experiment is **anonymous**, the data from your choices will only be linked to your station ID, never to your name. You will be paid privately at the end, after all participants have finished the experiment. During the experiment, you are not allowed to communicate with other participants. If you have a question at any time, please raise your hand and we will come to your desk.

Please read these instructions carefully and **answer the quiz (five questions)**. Once we have made sure that all participants have answered correctly, we will start the experiment. **At the end of the experiment** and before the payment, you will be asked to **fill out a short questionnaire**.

Thank you for your participation!

Your role: price forecasting on a chicken market

You are a farmer in a chicken market and have to ***submit price forecasts***. There are 10 farmers in the market, every farmer is a participant like you. The group of farmers will not change during the experiment. Every chicken produces the same number of eggs at the beginning of each period. Eggs are **either** traded for chickens in the market **or** consumed by the farmers. Eggs cannot be carried over between periods. You do not need to make trading decisions, a computerized trader will do it for you based on your forecasts.

Sequence of markets: You may play in several markets in a row

In each period after the first one*, an outbreak of avian flu may occur with a *constant and independent probability of 5%. If this happens, all chickens die and become worthless, and a new market starts. We will run **as many markets as possible** during the time for which you have been recruited. You will play in every market for at least **20 periods** because **you will only find out after 20 periods whether and in which period the chickens have died** from avian flu.

If the chickens have died within the first 20 periods, the market stops in period 20, you receive new chickens and **enter a new market**. If the chickens have not died within the first 20 periods, **you play for 20 more periods**, till period 40, and then observe whether the chickens have died between period 21 and period 40. If this is the case, a new market starts. If not, you continue in the market for another 20 periods, etc., till the chickens die and the market ends. **All periods after the chickens died will not be counted towards your earnings**.

At the beginning of each market, the **number of eggs produced per chicken** and the **number of chickens that you have received** will be displayed on your computer interface, which is mainly self-explanatory. The number of eggs per chicken **remains fixed for the whole market**. You never observe the number of chickens of the other 9 farmers.

Your task: Forecasting the price in the next period

In each period, your task is to **forecast the price** of a chicken ***in the next period***: in period 1, you have to forecast the price in period 2; in period 2, you have to forecast the price in period 3, etc. **Based on your forecasts, a computerized trader buys or sells chickens on your behalf**. Not all participants may have a computerized trader using forecasts for the next period, they may use a different time horizon.

The price of a chicken in terms of eggs is always adjusted so that the demand for chickens equals the supply (up to small random errors). The price depends on all participants' forecasts: if all participants forecast an **increase (resp. decrease) in the price**, the ***current*** **price** will tend to **increase (resp. decrease)**. **Once every participant has submitted a forecast**, the computers trade, **the current price of a chicken is determined** and you observe how many chickens you have bought or sold and your egg consumption. Your egg consumption is your amount of eggs at the beginning of the period plus the eggs you received from selling chickens (or minus the eggs you used to buy chickens). Your trader ensures that you always consume at least one egg and always have at least one chicken in any period.

Whether your trader buys or sells chickens depends both on *your forecast and the forecasts of the other participants*. The **higher your forecast compared to the forecasts of the other participants, the more chickens your trader buys**, and **the fewer eggs you consume now (but the more later on)**. The **lower your forecasts compared to the ones of the other participants, the more chickens your trader sells**, and **the more eggs you consume now (but the fewer later on)**.

Your payoff: forecasting accuracy and egg consumption

You may earn points in **two ways**. **First**, you may earn points based on your **price forecast accuracy**. The closer your forecast to the **realized price**, the higher your payoff. **There is a forecasting payoff table on your desk** that indicates how many points you make that way. If your prediction is perfect (zero error), you earn a maximum of 1100 points. If your forecast error is larger than 7, you earn zero point.

You receive your **first forecasting payoff** once the first price that you had to forecast becomes observable, that is **at the end of period 2**. Your corresponding forecast error is the difference between your forecast of the price in period 2 that you made in period 1 and the realized price in period 2.

If the chickens die, some of your last forecasts will not be rewarded because **only the price of living chickens counts towards the computation of the average price** that you had to forecast. For this reason, we pay **2 times your last rewarded forecast**, that is the one for which we can compute the price that you had to forecast. Your total forecasting payoff in each market is the sum of your realized forecasting payoff in that market.

Second, you may earn points with your **egg consumption**. **There is a consumption payoff table on your desk** that indicates how many points you earn that way. The more eggs you consume, the higher your consumption payoff. Notice that **consuming few eggs in one period** (e.g. 20) **and a lot in the next** (e.g. 980) **gives you *less* points** ($359+827=1186$, **see your payoff table!**) **than consuming an equal amount of eggs** (500) **in the two periods** ($746\times 2=1492$). Your total consumption payoff in each market is the sum of your consumption payoff in every period for which the chickens are alive.

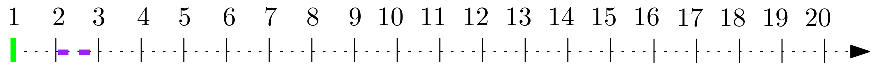
At the end of **each market**, you will be rewarded **either** with your total consumption **or** your total forecasting payoff **with equal probability**. This **does not depend** on how you have been rewarded in the previous markets. **If the chickens do not live for at least 2 periods, you will not have any forecasting score, so you will be rewarded with your consumption payoff**. All participants are paid in the same way.

Your total amount of points over all markets will be converted into euro and paid to you at the end of the experiment. One euro corresponds to 2000 points.

Example

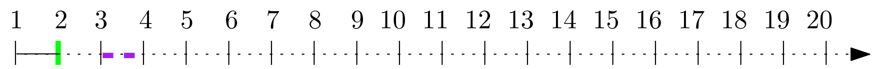
The box below provides an example of a sequence of events in a market where the chickens die in period 15, so you play until period 20.

You enter **period 1**.
You submit a forecast of the price in period 2:



You then observe P_1 (the price in **period 1**), the number of chickens you traded, your corresponding egg consumption and consumption points in period 1.

You enter **period 2**.
You submit a forecast of the price in period 3:

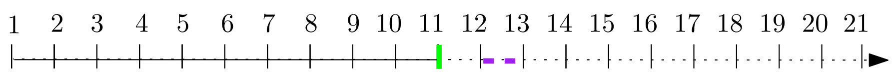


You then observe P_2. You then see your forecast error and forecasting payoff for your forecast made in period 1.

You also observe the number of chickens you traded, your corresponding egg consumption and consumption points in period 2.

⋮

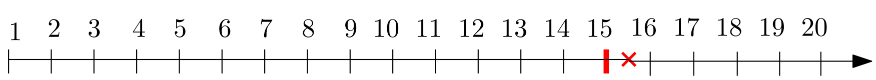
You enter **period 11**.
You submit a forecast of the price in period 12:



You observe P_{11}, your forecast made in period 10, your forecast error and corresponding forecasting payoff. You also observe the number of chickens you traded, your corresponding egg consumption and consumption points in period 11.

⋮

You enter **period 20**, you submit a prediction for period 21 **and then** observe whether the chickens have died during the last 20 periods: the chickens died **in period 15**, this market ends.



Your last forecasting payoff is for your forecast in period 14 of the price P_{15} in period 15. **This payoff is multiplied by 2.**
Your other forecasting payoffs are from period 1 (for period 2) till period 13 (for period 14). **Your forecasts made from period 15 till 20 are not rewarded.**
Your total consumption payoff is the sum of your consumption points from period 1 to 15. **Your egg consumption from period 16 till 20 is not rewarded.**

In this market, you earn **either** your consumption payoff **or** your forecasting payoff with equal probability. You then enter a new market.

Quiz

1. Assume you are at the end of period 13. Here is the sequence of realized prices:

   $p_1 = 32,\ p_2 = 61,\ p_3 = 77,\ p_4 = 78,\ p_5 = 120,\ p_6 = 42,\ p_7 = 96,\ p_8 = 100,\ p_9 = 90,\ p_{10} = 70,$ $p_{11} = 71$, $p_{12} = 46$, $p_{13} = 4$.

   (a) In period 12, what did you have to predict?

      i. The price in period 13.
      ii. The price in period 12.
      iii. The difference between the price in period 12 and in period 13.
      iv. None of the above.

   (b) Assume that, in period 12, you predicted a price of 2.5.

      i. What is your forecast error? ......
      ii. How many forecasting points do you earn? ......
      (**USE YOUR PAYOFF TABLE ON YOUR DESK!**)

2. What is the probability for all the chickens to die if you are entering...

   (a) ... period 6? ......

   (b) ... period 45? ......

3. If the chickens die in period 23, when will you find out?

4. If you forecast a high price for the next period, ...

   N.B.: Multiple answers may be possible.

   (a) Your forecast will not impact your demand for chickens.
   (b) Your trader is likely to buy chickens.
   (c) Your trader is likely to sell chickens.
   (d) You are likely to consume fewer eggs now but more later on.
   (e) You are likely to consume more eggs now but fewer later on.
   (f) This also depends on the other participants' forecasts.

5. If all participants tend to forecast an increase in the price in the future compared to past levels, what is the implication on the realized current market price?

   N.B.: Multiple answers may be possible.

   (a) The realized market price is likely to increase.
   (b) The realized market price is likely to decrease.
   (c) The realized market price is likely to remain stable.
   (d) The realized market price will not be impacted by participants' forecasts.

D.2 Instructions for long-horizon forecasters

Welcome to our experiment! The experiment is **anonymous**, the data from your choices will only be linked to your station ID, never to your name. You will be paid privately at the end, after all participants have finished the experiment. During the experiment, you are not allowed to communicate with other participants. If you have a question at any time, please raise your hand and we will come to your desk.

Please read these instructions carefully and **answer the quiz (five questions)**. Once we have made sure that all participants have answered correctly, we will start the experiment. **At the end of the experiment** and before the payment, you will be asked to **fill out a short questionnaire**.

Thank you for your participation!

Your role: price forecasting on a chicken market

You are a farmer in a chicken market and have to ***submit price forecasts***. There are 10 farmers in the market, every farmer is a participant like you. The group of farmers will not change during the experiment. Every chicken produces the same number of eggs at the beginning of each period. Eggs are **either** traded for chickens in the market **or** consumed by the farmers. Eggs cannot be carried over between periods. You do not need to make trading decisions, a computerized trader will do it for you based on your forecasts.

Sequence of markets: You may play in several markets in a row

In each period after the first one*, an outbreak of avian flu may occur with a *constant and independent probability of 5%. If this happens, all chickens die and become worthless, and a new market starts. We will run **as many markets as possible** during the time for which you have been recruited. You will play in every market for at least **20 periods** because **you will only find out after 20 periods whether and in which period the chickens have died** from avian flu.

If the chickens have died within the first 20 periods, the market stops in period 20, you receive new chickens and **enter a new market**. If the chickens have not died within the first 20 periods, **you play for 20 more periods**, till period 40, and then observe whether the chickens have died between period 21 and period 40. If this is the case, a new market starts. If not, you continue in the market for another 20 periods, etc., till the chickens die and the market ends. **All periods after the chickens died will not be counted towards your earnings**.

At the beginning of each market, the **number of eggs produced per chicken** and the **number of chickens that you have received** will be displayed on your computer interface, which is mainly self-explanatory. The number of eggs per chicken **remains fixed for the whole market**. You never observe the number of chickens of the other 9 farmers.

Your task: Forecasting the average price over the next 10 periods

In each period, your task is to **forecast the *average price*** of a chicken ***over the next 10 periods***: in period 1, you have to forecast the average price over period 2 to period 11 (i.e. the **average price over the next 10 periods**); in period 2, you have to forecast the average price over period 3 to period 12, etc. **Based on your forecasts, a computerized trader buys or sells chickens on your behalf**. Not all participants may have a computerized trader using forecasts for the next 10 periods, they may use a different time horizon.

The price of a chicken in terms of eggs is always adjusted so that the demand for chickens equals the supply (up to small random errors). The price depends on all participants' forecasts: if all participants forecast an **increase (resp. decrease) in the average price over the next 10 periods**, the ***current*** **price** will tend to **increase (resp. decrease)**. **Once every participant has submitted a forecast**, the computers trade, **the current price of a chicken is determined** and you observe how many chickens you have bought or sold and your egg consumption. Your egg consumption is your amount of eggs at the beginning of the period plus the eggs you received from selling chickens (or minus the eggs you used to buy chickens). Your trader ensures that you always consume at least one egg and always have at least one chicken in any period.

Whether your trader buys or sells chickens depends both on *your forecast and the forecasts of the other participants*. The **higher your forecast compared to the forecasts of the other participants, the more chickens your trader buys**, and **the fewer eggs you consume now (but the more later on)**. The **lower your forecasts compared to the ones of the other participants, the more chickens your trader sells**, and **the more eggs you consume now (but the fewer later on)**.

Your payoff: forecasting accuracy and egg consumption

You may earn points in **two ways**. **First**, you may earn points based on your **price forecast accuracy**. The closer your forecast to the realized ***average*** price, the higher your payoff. **There is a forecasting payoff table on your desk** that indicates how many points you make that way. If your prediction is perfect (zero error), you earn a maximum of 1100 points. If your forecast error is larger than 7, you earn zero point.

You receive your **first forecasting payoff** once the first average price that you had to forecast becomes observable, that is **in period 11**. Your corresponding forecast error is the difference between your forecast of the average price over the periods $2-11$ that you made in period 1 and the realized average price over the periods $2-11$.

If the chickens die, some of your last forecasts will not be rewarded because **only the price of living chickens counts towards the computation of the average price** that you had to forecast. For this reason, we pay **11 times your last rewarded forecast**, that is the one for which we can compute the average price that you had to forecast. Your total forecasting payoff in each market is the sum of your realized forecasting payoff in that market.

Second, you may earn points with your **egg consumption**. **There is a consumption payoff table on your desk** that indicates how many points you earn that way. The more eggs you consume, the higher your consumption payoff. Notice that **consuming few eggs in one period** (e.g. 20) **and a lot in the next** (e.g. 980) **gives you *less* points** ($359+827=1186$, **see your payoff table!**) **than consuming an equal amount of eggs** (500) **in the two periods** ($746\times 2=1492$). Your total consumption payoff in each market is the sum of your consumption payoff in every period for which the chickens are alive.

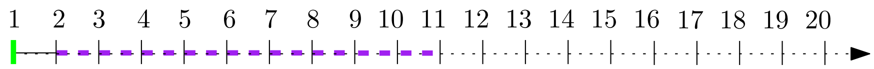
At the end of **each market**, you will be rewarded **either** with your total consumption **or** your total forecasting payoff **with equal probability**. This **does not depend** on how you have been rewarded in the previous markets. **If the chickens do not live for at least 11 periods, you will not have any forecasting score, so you will be rewarded with your consumption payoff**. All participants are paid in the same way.

Your total amount of points over all markets will be converted into euro and paid to you at the end of the experiment. One euro corresponds to 2000 points.

Example

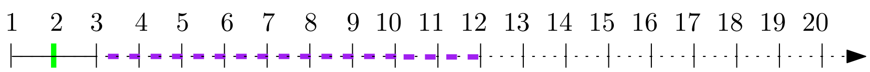
The box below provides an example of a sequence of events in a market where the chickens die in period 15, so you play until period 20.

You enter **period 1**.
Every player submits a forecast of the average price over periods 2 to 11:



You then observe P_1 (the price **in period 1**), the number of chickens you traded, your corresponding egg consumption and consumption points in period 1.

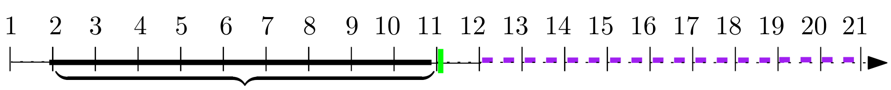
You enter **period 2**.
Every player submits a forecast of the average price from period 3 to 12:



You then observe P_2, the number of chickens you traded, your corresponding egg consumption and consumption points in period 2.

⋮

You enter **period 11**.
Every player submits a forecast of the average price from period 12 to 21:



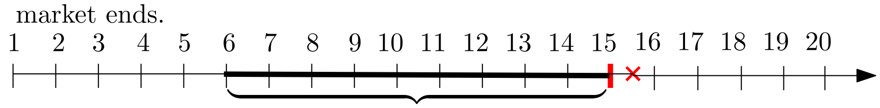
$$\tilde{P}_{2,11} = \frac{P_2+P_3+P_4+P_5+P_6+P_7+P_8+P_9+P_{10}+P_{11}}{10}$$

You observe P_{11} and the average price $\tilde{P}_{2,11}$ over period 2 to 11. You then see your forecast error and forecasting payoff for your forecast made in period 1.

You also observe the number of chickens you traded, your corresponding egg consumption and consumption points in period 11.

⋮

You enter **period 20**, submit a forecast for $\tilde{P}_{21,30}$ **and then** observe whether the chickens have died over the last 20 periods: the chickens died **in period 15**, this market ends.



$$\tilde{P}_{6,15} = \frac{P_6+P_7+P_8+P_9+P_{10}+P_{11}+P_{12}+P_{13}+P_{14}+P_{15}}{10}$$

Your last forecasting payoff is for your forecast in period 5 of the average price $\tilde{P}_{6,15}$ between periods 6 and 15 because the chickens have died in period 15, so we do not have prices afterwards. **This payoff is multiplied by 11.**
Your other forecasting payoffs are in period 1 (for periods 2 to 11), period 2 (for periods 3 to 12), period 3 (for periods 4 to 13) and period 4 (for periods 5 to 14).
Your forecasts made from period 6 till 20 are not rewarded.
Your total consumption payoff is the sum of your consumption points from period 1 to 15. **Your egg consumption from period 16 till 20 is not rewarded.**

In this market, you earn **either** your consumption payoff **or** your forecasting payoff with equal probability. You then enter a new market.

Quiz

1. Assume you are entering period 14. Here is the sequence of realized prices:

   $p_1 = 32,\ p_2 = 61,\ p_3 = 77,\ p_4 = 78,\ p_5 = 120,\ p_6 = 42,\ p_7 = 96,\ p_8 = 100,\ p_9 = 90,\ p_{10} = 70,$ $p_{11} = 71$, $p_{12} = 46$, $p_{13} = 4$.

   (a) In period 2, what did you have to predict?

   i. The price in period 3.
   ii. The average price over periods 3 to 12.
   iii. The average price over periods 2 to 11.
   iv. The difference between the price in period 3 and in period 11.
   v. The difference between the price in period 2 and in period 11.
   vi. None of the above.

   (b) Compute the average price over period 3 to 12: ......
   (**USE THE CALCULATOR ON YOUR DESK!**)

   (c) Assume that, in period 2, you predicted an average price over periods 3 to 12 of 82.5.

   i. What is your forecast error? ......
   ii. How many forecasting points do you earn? ......
   (**USE YOUR PAYOFF TABLE ON YOUR DESK!**)

2. What is the probability for all the chickens to die if you are entering...

   (a) ... period 6? ......

   (b) ... period 45? ......

3. If the chickens die in period 23, when will you find out?

4. If you forecast a high average price over the next 10 periods, ...

   N.B.: Multiple answers may be possible.

   (a) Your forecast will not impact your demand for chickens.
   (b) Your trader is likely to buy chickens.
   (c) Your trader is likely to sell chickens.
   (d) You are likely to consume fewer eggs now but more later on.
   (e) You are likely to consume more eggs now but fewer later on.
   (f) This also depends on the other participants' forecasts.

5. If all participants tend to forecast an increase in the price over the next 10 periods compared to past levels, what is the implication on the realized current market price?

   N.B.: Multiple answers may be possible.

   (a) The realized market price is likely to increase.
   (b) The realized market price is likely to decrease.
   (c) The realized market price is likely to remain stable.
   (d) The realized market price will not be impacted by participants' forecasts.

Forecasting payoff table

Your payoff : $1100 - \frac{1100}{49}\,(\text{Your forecast error})^2$

2000 points = 1 euro

error	points	error	points	error	points	error	points
0	1100	1.85	1023	3.7	793	5.55	409
0.05	1100	1.9	1019	3.75	784	5.6	396
0.1	1100	1.95	1015	3.8	776	5.65	383
0.15	1099	2	1010	3.85	767	5.7	371
0.2	1099	2.05	1006	3.9	759	5.75	358
0.25	1099	2.1	1001	3.95	750	5.8	345
0.3	1098	2.15	996	4	741	5.85	332
0.35	1097	2.2	991	4.05	732	5.9	319
0.4	1096	2.25	986	4.1	723	5.95	305
0.45	1095	2.3	981	4.15	713	6	292
0.5	1094	2.35	976	4.2	704	6.05	278
0.55	1093	2.4	971	4.25	695	6.1	265
0.6	1092	2.45	965	4.3	685	6.15	251
0.65	1091	2.5	960	4.35	675	6.2	237
0.7	1089	2.55	954	4.4	665	6.25	223
0.75	1087	2.6	948	4.45	655	6.3	209
0.8	1086	2.65	942	4.5	645	6.35	195
0.85	1084	2.7	936	4.55	635	6.4	180
0.9	1082	2.75	930	4.6	625	6.45	166
0.95	1080	2.8	924	4.65	615	6.5	152
1	1078	2.85	918	4.7	604	6.55	137
1.05	1075	2.9	911	4.75	593	6.6	122
1.1	1073	2.95	905	4.8	583	6.65	107
1.15	1070	3	898	4.85	572	6.7	92
1.2	1068	3.05	891	4.9	561	6.75	77
1.25	1065	3.1	884	4.95	550	6.8	62
1.3	1062	3.15	877	5	539	6.85	47
1.35	1059	3.2	870	5.05	527	6.9	31
1.4	1056	3.25	863	5.1	516	6.95	16
1.45	1053	3.3	856	5.15	505	error ≥ 7	0
1.5	1049	3.35	848	5.2	493		
1.55	1046	3.4	840	5.25	481		
1.6	1043	3.45	833	5.3	469		
1.65	1039	3.5	825	5.35	457		
1.7	1035	3.55	817	5.4	445		
1.75	1031	3.6	809	5.45	433		
1.8	1027	3.65	801	5.5	421		

Consumption payoff table

Your payoff : log(your egg consumption) $\times$ 120

2000 points = 1 euro

eggs	points	eggs	points	eggs	points	eggs	points
1	0	420	725	1000	829	12000	1127
2	83	440	730	1250	856	14000	1146
3	132	460	736	1500	878	16000	1162
4	166	480	741	1750	896	18000	1176
5	193	500	746	2000	912	20000	1188
6	215	520	750	2250	926	22000	1200
7	234	540	755	2500	939	24000	1210
8	250	560	759	2750	950	26000	1220
9	264	580	764	3000	961	28000	1229
10	276	600	768	3250	970	30000	1237
20	359	620	772	3500	979	32000	1245
30	408	640	775	3750	988	34000	1252
40	443	660	779	4000	995	36000	1259
50	469	680	783	4250	1003	38000	1265
60	491	700	786	4500	1009	40000	1272
70	510	720	790	4750	1016	42000	1277
80	526	740	793	5000	1022	44000	1283
90	540	760	796	5250	1028	46000	1288
100	553	780	799	5500	1034	48000	1293
120	575	800	802	5750	1039	50000	1298
140	593	820	805	6000	1044	52000	1303
160	609	840	808	6250	1049	54000	1308
180	623	860	811	6500	1054	56000	1312
200	636	880	814	6750	1058	58000	1316
220	647	900	816	7000	1062	60000	1320
240	658	920	819	7250	1067	62000	1324
260	667	940	822	7500	1071	64000	1328
280	676	960	824	7750	1075	66000	1332
300	684	980	827	8000	1078	68000	1335
320	692	1000	829	8250	1082	70000	1339
340	699	1020	831	8500	1086	72000	1342
360	706	1040	834	8750	1089	74000	1345
380	713	1060	836	9000	1093	76000	1349
400	719	1080	838	10000	1096	80000	1352

Once you have finished the experiment, please fill out this questionnaire!

Table number (letter and number on the yellow card): _______

Gender
☐ male
☐ female
☐ other

Age: _______

Nationality:______________

Which of the following *comes closest* to your field of study?
☐ Economics, Business
☐ Psychology, Social Sciences, Law, Humanities
☐ Mathematics, Physics, IT
☐ Medicine, Biology, Chemistry,
☐ Other: _____
☐no studies

How would you describe your command of English?
☐ Excellent
☐ Very good
☐ Good
☐ Satisfactory
☐ Poor

How clear were the instructions of the experiment?
☐ Very clear
☐ Clear
☐ Understandable
☐ Slightly confusing
☐ Confusing

Have you participated in a *similar* economic experiment before?
☐ yes
☐ no

Did you perceive the length of the markets to be:
☐As announced in the instructions
☐ Longer than announced in the instructions
☐ Shorter than announced in the instructions

Could you, in few words, summarize your strategy(ies) in this experiment?

____
____
____

If you would like to leave any comments for us, please do so here:

____
____
____