Online Appendix
Distributing scarce jobs and output: Experimental evidence on the dynamic effects of rationing

Guidon Fenig and Luba Petersen *

December 22, 2016

A Theoretical model

The framework that we use to implement our experimental design is based on a representative agent dynamic general equilibrium (DGE) model with sticky prices and monopolistic competition. In order to have a constant fundamental value for the asset that we introduce, we assume that the economy is subject to no shocks and therefore our model is not stochastic. However, the framework can be easily extended to include various shocks, in which case it will be a dynamic stochastic general equilibrium (DSGE) model. The choice of this particular framework is motivated by the fact that DGE (and DSGE) models are widely used for monetary policy analysis and forecasting among central banks. In this model households optimally choose their consumption of final goods, labor supply, and savings. Final goods are produced by monoplistically competitive firms that use labor as their only input. Firms set their prices based on the staggered pricing mechanism *à la* Calvo (1983). Finally, the central bank sets the nominal interest rate in response to fluctuations in inflation. We begin with a description of the model

*Corresponding author: Luba Petersen: lubap@sfu.ca.

and provide a characterization of the behavior of households and their optimal decisions. Then we describe the production and price-setting decisions of firms, and finally we show how the central bank conducts monetary policy.

Households

Households maximize the present discounted value of their utility associated with consumption and labor as follows:

$$U_t = \sum_{j=0}^{\infty} \beta^j \left(\frac{c_{t+j}^{1-\sigma}}{1-\sigma} - \frac{h_{t+j}^{1+\eta}}{1+\eta} \right), \tag{1}$$

where

$$c_t = \left(\int_0^1 c_{it}^{\frac{\theta-1}{\theta}} di \right)^{\frac{\theta}{\theta-1}}. \tag{2}$$

They obtain utility from the immediate consumption of a bundle of differentiated varieties, each variety denoted by c_{it}, and disutility from working h_t hours. The elasticity of intertemporal substitution is represented by $1/\sigma$, the elasticity of labor supply by $1/\eta$, and the elasticity of substitution between different varieties by θ.

Equation (3) is the household's budget constraint that equates expenditures to income:

$$P_t c_t + B_t = (1 + i_{t-1}) B_{t-1} + W_t h_t + T_t. \tag{3}$$

Households may purchase a consumption good, c_t, at a price, P_t; save or borrow through a risk-free nominal bond, B_t, and earn interest-rate income or pay interest on debt, $(1 + i_{t-1})B_{t-1}$, on bond holdings; earn wage income from working, $W_t h_t$; and receive a transfer, T_t, from the monopolistic firms. The representative household maximizes its utility stream (1) by making optimal choices on c_t, h_t, and B_t subject to the budget constraint (3).

From the household's first order conditions the following equations are derived:

$$\frac{h_t^{\eta}}{c_t^{-\sigma}} = \frac{W_t}{P_t}, \text{ and} \tag{4}$$

$$\beta\left[\left(\frac{c_{t+1}}{c_t}\right)^{-\sigma}\frac{(1+i_t)}{(1+\pi_{t+1})}\right]=1. \tag{5}$$

Equation (4) describes the labor–leisure intratemporal trade-off taking the real wage as given. Equation (5) represents the intertemporal tradeoff between current and future consumption in terms of the risk-free bond. Real interest can be defined using the Fisher equation:

$$1+r_t=\left(\frac{1+i_t}{(1+\pi_{t+1})}\right). \tag{6}$$

Firms

Firms possess a linear production function and operate in a monopolistically competitive environment. They sell differentiated goods, Y_i, using labor as the sole input in the production process:

$$Y_{it}=Zh_{it}. \tag{7}$$

Here, h_{it} is the number of hours of work hired by the firms and Z is a productivity parameter. Firms must decide what price to set for the output. In each period, only a fraction $1-\omega$ of the firms are allowed to adjust their prices (Calvo (1983) mechanism). The prices set by the firms determine the demand for each variety:

$$Y_{it}=\frac{1}{I}\left(\frac{P_{it}}{P_t}\right)^{-\theta}Y_t, \tag{8}$$

where I is the number of firms in the economy. P_t is the aggregate price index and is defined as

$$P_t\equiv I^{\frac{1}{\theta-1}}\left\{\left[\sum_{i=1}^{I}(P_{it})^{1-\theta}\right]\right\}^{\frac{1}{1-\theta}}. \tag{9}$$

The Calvo assumption about price stickiness can be also written as

$$P_t^{1-\theta}=(1-\omega)\left(P_t^o\right)^{1-\theta}+\omega\left(P_{t-1}\right)^{1-\theta}. \tag{10}$$

One important feature about the firms is that output is "made-to-order", which implies that all output that is produced has to be consumed. In other words, there are no inventories and this is why excess resources have to be rationed.

Monetary Policy

The central bank sets the nominal interest rate on bonds according to the following Taylor rule:

$$\frac{(1+i_t)}{(1+\rho)} = \left(\frac{1+i_{t-1}}{1+\rho}\right)^{\gamma} \left[(1+\pi_t)^{\delta}\right]^{1-\gamma}, \tag{11}$$

where ρ is the natural nominal interest rate. Also important to notice is that when $\gamma > 0$, the central bank exhibits interest-rate smoothing behavior. Our decision to incorporate interest-rate smoothing was motivated by a desire to provide stability in policy.

Market Clearing

In order to close the model, we need to impose market clearing conditions on asset markets. Note that in a DGE, the net supply of bonds is zero and the fixed supply of the shares of the risky asset is normalized to one:

$$B_t = 0, \text{ and } X_t = 1. \tag{12}$$

We also impose that total demand for output is financed by income from output production:

$$C_t = Y_t. \tag{13}$$

Steady State Equilibrium

To derive the steady state equilibrium, one can start by solving the cost minimization problem for firm i (equation (7)):

$$\min_{h_{it}} \left(\frac{W_t}{P_t}\right) h_{it} - \varphi_t \left(Y_{it} - Z h_{it}\right) \tag{14}$$

where φ_t is the firm's real marginal cost. From the first order condition, the following equation is obtained:

$$mc_t \equiv \varphi_t = \frac{W_t}{P_t}\frac{1}{Z}. \tag{15}$$

It can be shown that the ratio of the price set by the firms when they are able to update it, P_t^o, relative to the aggregate price index, P_t, is

$$\frac{P_t^o}{P_t} = \frac{\theta}{\theta-1}\frac{\sum_{i=1}^{\infty}\omega^i\beta^i c_{t+i}^{1-\sigma} mc_{t+i}\left(\frac{P_{t+i}}{P_t}\right)^{\theta}}{\sum_{i=1}^{\infty}\omega^i\beta^i c_{t+i}^{1-\sigma}\left(\frac{P_{t+i}}{P_t}\right)^{\theta-1}} \equiv \frac{\theta}{\theta-1}\frac{S1_t}{S2_t}, \tag{16}$$

where

$$S1_t = c_t^{1-\sigma} mc_t + \beta\omega E_t S1_{t+1}, \text{ and} \tag{17}$$

$$S2_t = c_t^{1-\sigma} + \beta\omega E_t S2_{t+1}. \tag{18}$$

With no shocks in the economy, $S1_t = S1_{t+1}$ and $S2_t = S2_{t+1}$. This implies that

$$\frac{P_t^o}{P_t} = \frac{\theta}{\theta-1} mc_t. \tag{19}$$

Thus, in the steady state,

$$\frac{W}{P} = \frac{\theta-1}{\theta} Z. \tag{20}$$

Using the market clearing conditions and equation (4), the steady state values for labor and consumption are obtained:

$$h^{SS} = \left(\frac{\theta-1}{\theta} Z^{1-\sigma}\right)^{\frac{1}{\eta+\sigma}}, \text{ and} \tag{21}$$

$$c^{SS} = Z\left(\frac{\theta-1}{\theta} Z^{1-\sigma}\right)^{\frac{1}{\eta+\sigma}}. \tag{22}$$

From Equation (5) the steady state for the interest rate can be obtained:

$$i^{SS} = \frac{1}{\beta} - 1. \tag{23}$$

Derivation of the inflation equation

Combining equations (4), (10), and (19), the following equation for inflation is obtained:

$$\pi_t = \frac{\omega^{\frac{1}{1-\theta}}}{\left[1 - (1-\omega)\left(\frac{\theta}{\theta-1}\frac{h_t^{\eta} c_t^{\sigma}}{Z}\right)^{1-\theta}\right]^{\frac{1}{1-\theta}}} - 1. \tag{24}$$

Linearizing (24), by using a first order Taylor approximation around the steady state, linearized inflation is obtained:

$$\pi_t = 1 + \gamma^c (c_t^{med} - c^{SS}) + \gamma^h (h_t^{med} - h^{SS}), \tag{25}$$

where

$$\gamma^c = \frac{1}{(1-\theta) Z} \left(c^{SS}\right)^{\sigma-1} \left(h^{SS}\right)^{\eta} \sigma\theta(\omega - 1)\omega^{\frac{1}{1-\theta}} \Psi, \tag{26}$$

$$\gamma^h = \frac{1}{(1-\theta) Z} \left(c^{SS}\right)^{\sigma} \left(h^{SS}\right)^{\eta-1} \eta\theta(\omega - 1)\omega^{\frac{1}{1-\theta}} \Psi, \tag{27}$$

and

$$\Psi = \left(1 - (1-\omega)\left(\frac{\left(c^{SS}\right)^{\sigma}\left(h^{SS}\right)^{\eta}\theta}{(\theta-1) Z}\right)^{1-\theta}\right)^{-\left(1+\frac{1}{1-\theta}\right)} \left(\frac{\left(c^{SS}\right)^{\sigma}\left(h^{SS}\right)^{\eta}\theta}{(\theta-1) Z}\right)^{-\theta}. \tag{28}$$

B Parametrization

We choose parameter values for our environment based on two considerations. First, we aimed to be close to U.S. quarterly data. Second, our aim was ensure a sufficiently interior steady state and steep expected payoff hills to clearly observe actively chosen deviations from equilibrium behavior (these parameters are presented in Table 1). We set the discount factor (framed in our environment as the probability of continuation of the sequence) β equal to 0.965. This implies that a particular sequence of periods would last for an average of 28 periods. The inverse of the elasticity of intertemporal substitution, σ, is calibrated to be 0.33, while the labor supply parameter, η, is set to 1.5. The elasticity of substitution between varieties, θ, is 15, implying a markup of 7% over marginal cost. The Calvo parameter, ω, is 0.9, implying that 10% of firms have the ability to update their prices each period. The interest-rate smoothing parameter used by the central bank is 0.5, while the Taylor rule parameter, indicating how responsive the nominal interest rate is to inflation, is $\delta = 1.5$. The per-period dividend paid on assets is 0.035, which means that the asset is worth 1 after an average of 28 periods. We set a fixed fundamental value to minimize subjects' confusion. Each firm produces $Z = 10$ units of output with 1 unit of labor. In the steady state, the selected calibration implies steady state levels of individual consumption and labor of 22.4 and 2.24 units, respectively. The steady state real wage is set to 9.35, and the steady state nominal rate of return is 0.036.

Table 1: Parameters and Steady State Values

Parameter	Parameter Description	Value
Z	Productivity level	10
$1-\omega$	Fraction of firms updating	0.1
δ	Inflation target of the central bank	1.5
γ	Interest smoothing parameter	0.5
θ	Measure of substitutability	15
β	Rate of discounting	0.965
ρ	Natural nominal rate of return	0.0363
$1/\sigma$	Elasticity of intertemporal substitution	3.03
$1/\eta$	Frisch labor supply elasticity	0.67
μ^*	Steady state markup $(\theta/(\theta-1))$	1.07
C^*	Steady state consumption	22.37
N^*	Steady state labor	2.237
W^*	Steady state nominal wage	10
P^*	Steady state output price	1.07

C Aggregate Variables

Figure 1: Median Labor Supply per Session

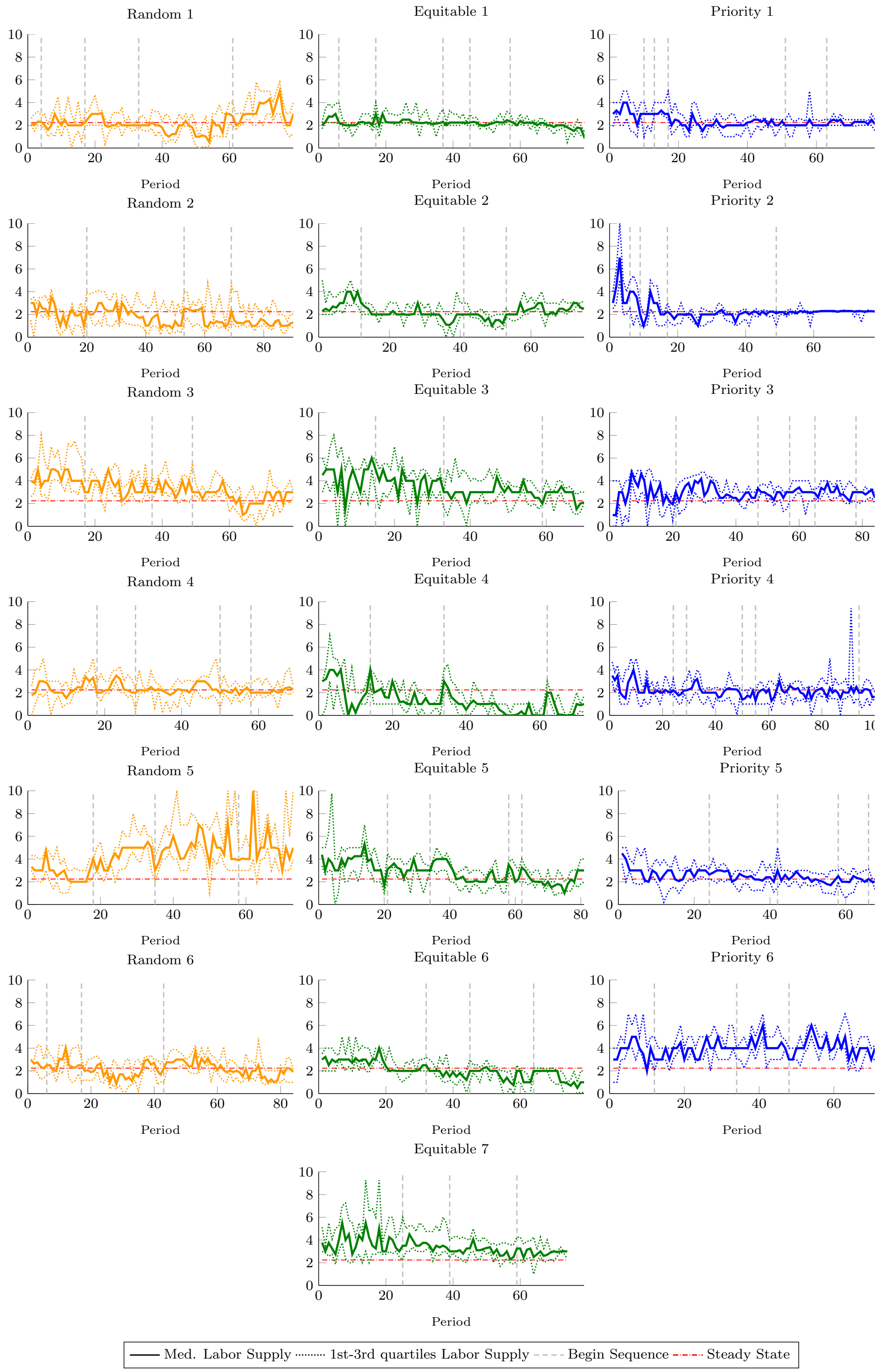
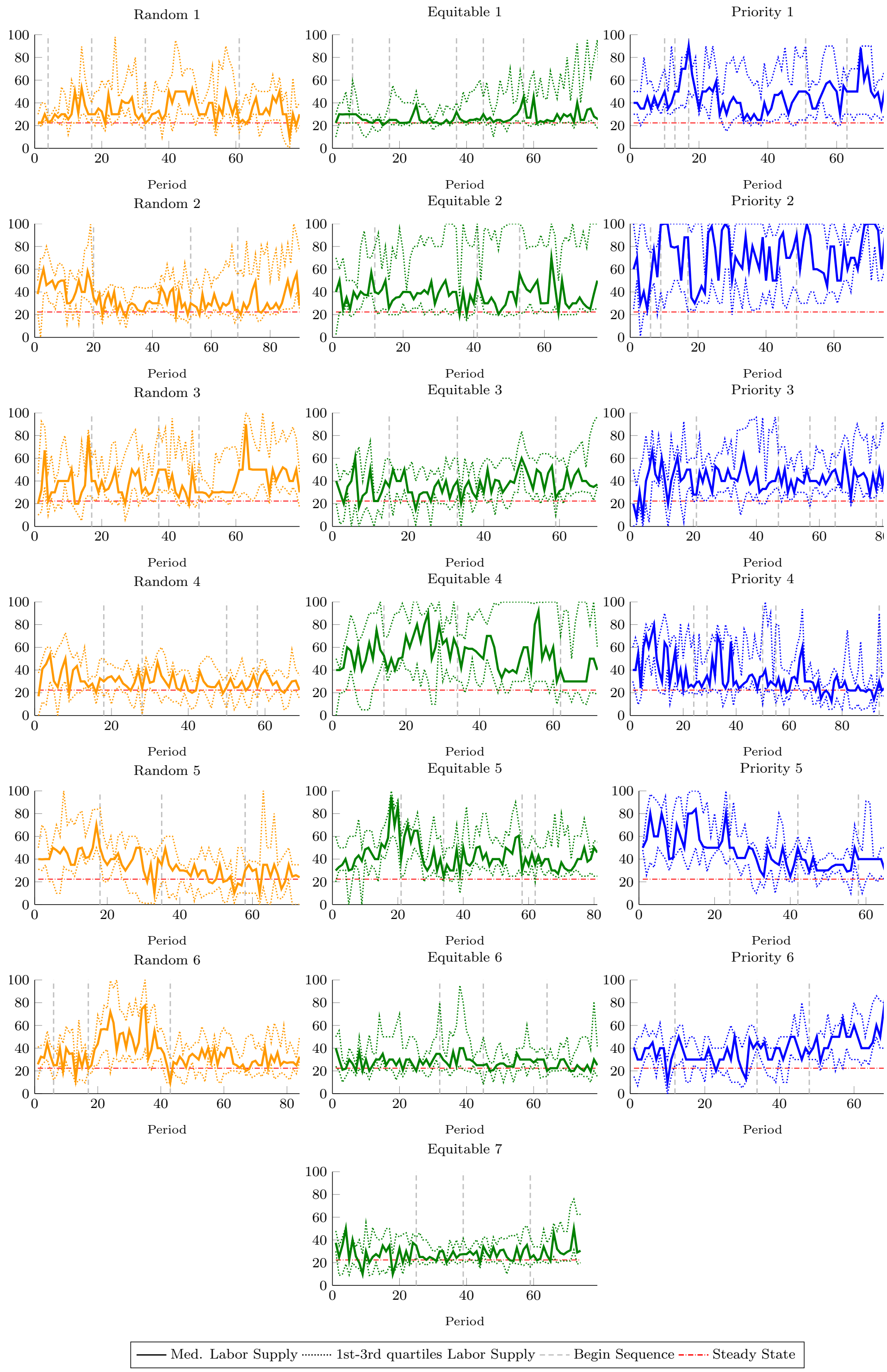


Figure 2: Median Output Demand per Session



D The effects of output rationing on decisions

We utilize our rich panel-level data with subject-level observations collected every period to gain insight into the effects of rationing schemes on individual labor and output decisions. Our main estimating equation is motivated by the intra-temporal optimization equation of households, which suggests that increases in real wages and output demand (labor supply) is associated with an increase in labor supply (output demand). We further consider the effects of entering bank account balances, as well as the effects of experiencing output rationing and the quantity of rationing incurred in the previous period on current decisions. Our focus on output rationing stems from the earlier observation that the vast majority of instances of rationing are of output.

A series of pre-estimation diagnostic tests are conducted to determine appropriate estimation strategies. We use our first specification in Table 2 as our baseline testing specification and apply the recommended estimation strategy to all other specifications. First, a Hausman test rejects the null hypothesis that the preferred model is one with random effects in favour of the alternative of fixed effects ($p = 0.000$). A further test for random effects (Breusch-Pagan Lagrange multiplier test) is unable to reject the null hypothesis that the variance across subjects is zero ($p = 1.000$). That is, we are advised to use ordinary least squares (OLS) rather than assume random effects. A Pesaran cross-sectional dependence test rejects the null hypothesis that residuals are not correlated across subjects ($p = 0.000$), implying that our standard errors should be corrected for cross-sectional dependence. A modified Wald test identifies group heteroskedasticity within a fixed effects regression specification ($p = 0.000$). Finally, we test for serial correlation between variables and reject the null hypothesis of no serial correlation ($p = 0.000$). The results of the diagnostic tests motivate us to consider a fixed effect panel regression in which we employ robust standard errors to correct for heteroskedasticity and autocorrelation. Given our limited number of sessions per treatment, we do not cluster our standard errors.

We conduct numerous regressions to understand how rationing influences decisions within a treatment. The treatment-specific results are presented in Tables 2, with labor supply decisions presented in Panel A and output demand decisions in Panel B. All specifications include controls for real wages, past and current decisions, and end-of-period bank account balances from the previous period, and they vary by the modelling of output rationing. Specification (1) includes the dummy variable $OutputRationed_{i,t-1}$, which takes the value of 1 if a subject received less output than she demanded in the previous period. Specification (2) includes the variable $QuantityOutputRationed_{i,t-1}$, which is a continuous variable measuring the difference between what a subject demanded in output and what she received in the previous period. Specification (3) instead considers an alternative measure of output rationing, $AltQuantityOutputRationed_{i,t-1}$, which is measured as the difference between the amount of output a participant was willing to produce and the potentially rationed amount she received, $min(0, min(10N^S_{i,t-1}, C^D_{t-1}) - c_{i,t-1})$. This alternative measure allows us to account for rationing that an individual subject incurred because another participant was allocated her production. This alternative rationing notion is absent from the Priority rule specifications, as under a Priority rule all participants are able to receive the output they were hired to produce. To identify differentiated reactions of labor supply and output demand to rationing across treatments, we conduct a further set of regressions that pools data from all three treatments in which our various rationing measures interact with treatment dummies. The results can be found in Table 3.

Labor Supply Response to Output Rationing. As seen in Table 2, evaluating each treatment independently, we find that experiencing any output rationing in the previous period leads subjects to significantly reduce their current labor supply, from 0.2 hours in the Equitable treatment to 0.43 hours in the Random treatment. Comparing the treatments in a pooled regression with treatment interactions, we observe that the negative labor supply response to past output rationing is significantly more pronounced in the Equitable and Random treatments. Controlling for other determinants of labor supply, we find that output-rationed Equitable and Random participants will work 0.23

and 0.38 hours less, respectively, than their Priority counterparts. Similar results are observed in Specification (2) when we instead consider the effects of increasing the degree of rationing. Participants in the Random and Equitable significantly decrease their labor supply by 0.008 and 0.009 hours for every unit of output rationed. By contrast, the average Priority participant adjusts her labor supply downward by only 0.003 hours for each unit of output rationed and this reaction is not significantly different from zero. Comparing across treatments, we again observe a significantly larger response to output rationing in the Equitable and Random treatments than in the Priority treatment. Compared to rationed participants in the Priority treatment, rationed Equitable workers supply 0.23 fewer hours while rationed Random participants supply 0.38 fewer hours. These differences are statistically significant at the 1% level.

Labor supplies in the Random and Equitable treatments also respond adversely to increases in the quantity of output rationed. Random and Equitable participants significantly reduce their labor supply by 0.08 and 0.09 hours, respectively, for every 10 units they were unable to purchase in the previous period. In contrast, Priority participants reduce their labor supply by 0.03 hours for every 10 units rationed, but this reaction is not statistically significant. Compared to their counterparts in the Priority treatment, Equitable and Random participants have a significantly more adverse reaction to output rationing. We observe an even more pronounced response when we instead consider the $AltQuantityOutputRationed_{i,t-1}$ measure of output rationing. Ten units of output rationing leads the average Random and Equitable participants to significantly reduce their labor supply by 0.16 and 0.29 hours, respectively. Compared to their Random counterparts, Equitable participants' labor supplies are significantly more sensitive to being rationed output they personally produced.

Output Demand Response to Rationing. Results for output demand decisions are presented in Panel B of Table 2. Simply being unable to satiate last period's demands leads Random participants to significantly increase their demands by 7.2 units, but leads to small and insignificantly lower demands in the Equitable treatment and small and insignificantly higher demands in the Priority treatment. Rationed Random participants demand significantly more than their Priority and Equitable counterparts, but the difference between the latter two treatments is not significant.

The treatment-specific reactions to facing output rationing is presented in each column (1) of Panel B. We observe Priority participants increase their output demand on average by 14.3 units in response to rationing. The reaction is significantly muted in the Equitable treatment, with consumption demand increasing by only 10 units. Compared to reactions under the Priority treatment, reactions in the Random treatment are also smaller on average but the difference is not statistically significant. In column (6) of the pooled regressions, we observe that compared to participants in the Random treatment, Equitable participants are not significantly more or less reactive to output rationing. In terms of quantity rationing, the greater the extent of rationing, the more a participant will demand in the following periods. Relative to Priority participants, the increase in consumer demand is significantly and quantitatively larger among Equitable and Random participants (with no significant differences between the latter two).

Each column (2) in Panel B of Table 2 presents output demand responses to the quantity of output rationed. Rationed participants in all treatments increase their output demands in response to greater rationing in the previous period. While demands increase from an additional 0.134 units per unit previously rationed in the Priority treatment up to 0.317 units in the Equitable treatment, the differences are not significant across treatments. When we instead consider the $AltQuantityOutputRationed_{i,t-1}$ measure of output rationing in column (3), we observe significant increases in output demand only in the Random treatment as the number of units of output rationed increases. Equitable demands are largely unresponsive to this form of output rationing.

The above results suggest that rationing schemes do have important effects on labor and consumption decisions. Random and Equitable labor supply decisions are considerably more reactive to rationing. In these treatments, rationing may be a consequence of others' free-riding. By contrast, in the Priority treatment, rationing can occur only if a participant wants to consume more than she has produced and there is insufficient excess supply to draw on. Conversely, consumption decisions are less reactive to the quantity of output rationing in the Random and Equitable treatments. Participants in the Random treatment who demand excessive quantities of output face a greater probability of receiving the units (and a higher consumption bill) than those in the Priority treatment, resulting in more cautious decisions. Moreover, asking for relatively more output in the Random treatment drains the available pool for others. In the Equitable treatment, demanding higher levels of output is less likely to influence overall output received since everyone receives an equal share of the production up to their personal demands. Taken together, these results suggest that in response to past output rationing, a priority rationing scheme provides the greatest stability in labor hours supplied at the cost of increased demand for output. However, because one subjects' excess demands do not influence others' allocations, the Priority allocation scheme ensures the greatest stability in aggregate labor supply and production.

Table 2: Labor supply and output demand decisions by treatment[I]

Panel A	Random Queue rule			Equitable rule			Priority rule	
Dep.Var. Labor Supply	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)
W_t/P_t	0.039***	0.040***	0.041***	0.068***	0.066***	0.068***	0.063***	0.063***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
$N^S_{i,t-1}$	0.362***	0.363***	0.387***	0.302***	0.287***	0.341***	0.197***	0.196***
	(0.04)	(0.04)	(0.04)	(0.03)	(0.03)	(0.04)	(0.04)	(0.04)
B_{t-1}	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000**	-0.000***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
$C^D_{i,t}$	-0.004	-0.004	-0.005	-0.006	-0.002	-0.006	0.001	0.002
	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)	(0.00)	(0.00)	(0.00)
$OutputRationed_{t-1}$	-0.432***			-0.200**			-0.204**	
	(0.08)			(0.09)			(0.09)	
$QuantityOutputRationed_{t-1}$		-0.008***			-0.009***			-0.003
		(0.00)			(0.00)			(0.00)
$Alt.QuantityOutputRationed_{t-1}$			-0.016***			-0.029***		
			(0.00)			(0.01)		
α	1.829***	1.735***	1.694***	1.497***	1.486***	1.367***	1.543***	1.475***
	(0.17)	(0.16)	(0.17)	(0.25)	(0.25)	(0.26)	(0.16)	(0.16)
N	3881	3881	3881	4668	4668	4668	4133	4133
F	61.99	58.45	52.04	47.84	92.59	43.68	27.90	29.32

Panel B	Random Queue rule			Equitable rule			Priority rule	
Dep.Var. Output Demand	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)
W_t/P_t	0.197**	0.208**	0.145*	0.097	0.331***	0.125	0.303***	0.340***
	(0.08)	(0.08)	(0.08)	(0.12)	(0.11)	(0.12)	(0.10)	(0.10)
$C^D_{i,t-1}$	0.391***	0.341***	0.402***	0.457***	0.222***	0.446***	0.486***	0.391***
	(0.03)	(0.04)	(0.03)	(0.05)	(0.04)	(0.05)	(0.03)	(0.04)
B_{t-1}	0.001	0.001	0.001	0.000	0.000	0.000	0.002***	0.002***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
$N^S_{i,t}$	-0.673	-0.656	-0.904	-0.915	-0.297	-0.868	0.189	0.383
	(0.63)	(0.64)	(0.61)	(0.89)	(0.90)	(0.90)	(0.81)	(0.84)
$OutputRationed_{t-1}$	7.187***			-1.724			0.035	
	(1.57)			(1.18)			(1.31)	
$QuantityOutputRationed_{t-1}$		0.186***			0.317***			0.134***
		(0.04)			(0.06)			(0.04)
$Alt.QuantityOutputRationed_{t-1}$			0.199***			-0.080		
			(0.07)			(0.11)		
α	21.967***	23.859***	24.143***	26.708***	25.822***	26.014***	21.418***	22.118***
	(2.18)	(2.12)	(2.09)	(2.82)	(2.82)	(2.88)	(2.74)	(2.54)
N	3881	3881	3881	4668	4668	4668	4133	4133
F	49.92	49.55	36.37	27.05	32.72	25.48	55.51	60.06

(I) This table presents results from a series of fixed effect panel regressions. $C^D_{i,t}$ and $N^S_{i,t}$ refer to current period output demands and labor supplies. $Bank_{i,t-1}$ refers to the end-of-period bank account balance in period $t-1$. $OutputRationed_{i,t-1}$ takes the value of 1 if, in the previous period, participant i received less output than she demanded, and 0 otherwise. $QuantityOutputRationed_{i,t-1}$ measures the amount by which the participant was rationed on output in the previous period. $AltQuantityOutputRationed_{i,t-1}$ measures the difference between the amount of output a participant was willing to produce and the potentially rationed amount received. Robust standard errors are employed. $^*p < 0.10$, $^{**}p < 0.05$, and $^{***}p < 0.01$.

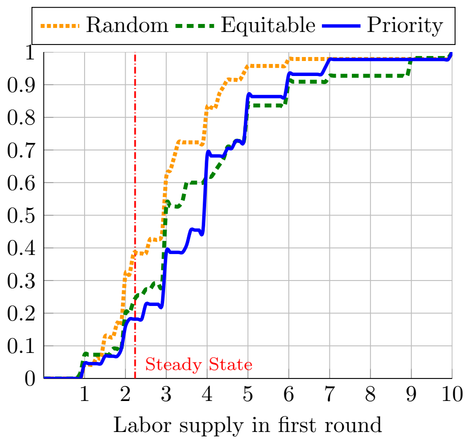
Table 3: Treatments effects of rationing schemes on labor supply and output demand decisions[I]

	Labor Supply Decisions					Output Demand Decisions				
	(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)
W_t/P_t	0.057***	0.057***	0.056***	0.056***	0.054***	0.197***	0.197***	0.276***	0.276***	0.133*
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.06)	(0.06)	(0.05)	(0.05)	(0.07)
$N^S_{i,t-1}$	0.294***	0.294***	0.289***	0.289***	0.369***					
	(0.02)	(0.02)	(0.02)	(0.02)	(0.03)					
$N^S_{i,t}$						-0.463	-0.463	-0.225	-0.225	-0.885
						(0.45)	(0.45)	(0.46)	(0.46)	(0.54)
B_{t-1}	-0.000**	-0.000**	-0.000**	-0.000**	-0.000*	0.001**	0.001**	0.001**	0.001**	0.001
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
$C^D_{i,t}$	-0.003	-0.003	-0.002	-0.002	-0.006*					
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)					
$C^D_{i,t-1}$						0.447***	0.447***	0.333***	0.333***	0.425***
						(0.02)	(0.02)	(0.03)	(0.03)	(0.03)
$OutputRationed_{t-1}$	-0.059	-0.438***				1.098	6.845***			
	(0.08)	(0.08)				(1.45)	(1.45)			
$OutputRationed_{t-1} \times EQ$	-0.227**	0.153				-1.735	-7.482***			
	(0.10)	(0.11)				(1.79)	(1.69)			
$OutputRationed_{t-1} \times RQ$	-0.379***					5.747***				
	(0.12)					(1.91)				
$OutputRationed_{t-1} \times PR$		0.379***					-5.747***			
		(0.12)					(1.91)			
$QuantityOutputRationed_{t-1}$			0.000	-0.008***				0.186***	0.198***	
			(0.00)	(0.00)				(0.04)	(0.04)	
$QuantityOutputRationed_{t-1} \times EQ$			-0.010***	-0.002				0.028	0.016	
			(0.00)	(0.00)				(0.06)	(0.06)	
$QuantityOutputRationed_{t-1} \times RQ$			-0.008***					0.012		
			(0.00)					(0.04)		
$QuantityOutputRationed_{t-1} \times PR$				0.008***					-0.012	
				(0.00)					(0.04)	
$Alt.QuantityOutputRationed_{t-1}$					-0.034***					-0.061
					(0.01)					(0.11)
$Alt.QuantityOutputRationed_{t-1} \times RQ$					0.019**					0.254**
					(0.01)					(0.13)
α	1.607***	1.607***	1.560***	1.560***	1.516***	23.326***	23.326***	23.961***	23.961***	25.241***
	(0.12)	(0.12)	(0.11)	(0.11)	(0.16)	(1.56)	(1.56)	(1.50)	(1.50)	(1.85)
Treatments	All	All	All	All	EQ, RQ	All	All	All	All	EQ, RQ
N	12682	12682	12682	12682	8549	12682	12682	12682	12682	8549
F	81.51	81.51	120.8	120.8	71.56	83.16	83.16	96.13	96.13	47.20

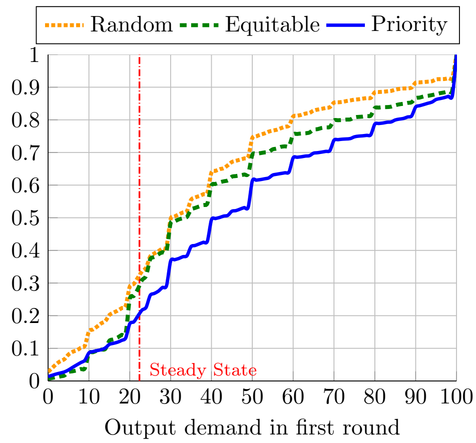
(I) This table presents results from a series of fixed effect panel regressions. $C^D_{i,t}$ and $N^S_{i,t}$ refer to current period output demands and labor supplies. $Bank_{i,t-1}$ refers to the end-of-period bank account balance in period $t-1$. $OutputRationed_{i,t-1}$ takes the value of 1 if, in the previous period, participant i received less output than she demanded, and 0 otherwise. $QuantityOutputRationed_{i,t-1}$ measures the amount by which the participant was rationed on output in the previous period. $AltQuantityOutputRationed_{i,t-1}$ measures the difference between the amount of output a participant was willing to produce and the potentially rationed amount received In specification (5), PR is omitted from the regression as all observations of $Alt.QuantityRationed$ are equal to zero in that treatment. Robust standard errors are employed. $*p < 0.10$, $**p < 0.05$, and $***p < 0.01$.

E Labor Supply and Output Demand in Period 1

Figure 3: Cumulative Distribution Functions of Individual Labor Supply and Output Demand in Period 1



(a) CDF Individual Labor Supply in Period 1



(b) CDF Individual Output Demand in Period 1

Note: These figures display labor supply and median output demand for each subject/period in period 1. We excluded observations for which subjects did not submit their decisions on time (when this was the case the decisions were recorded as zero units of labor requested and zero units of output requested).

F Computer Interfaces

Figure 4: Main screen

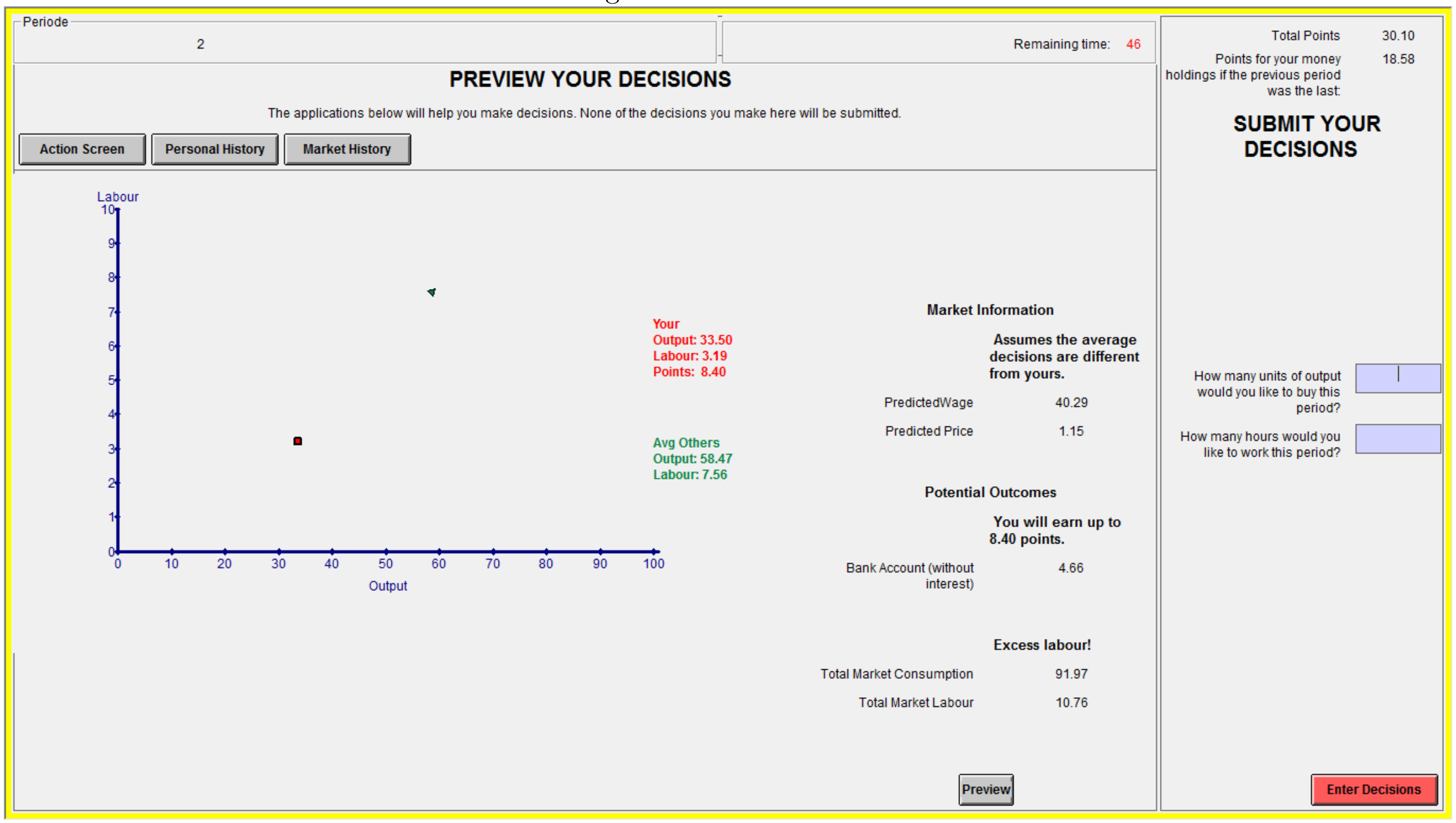
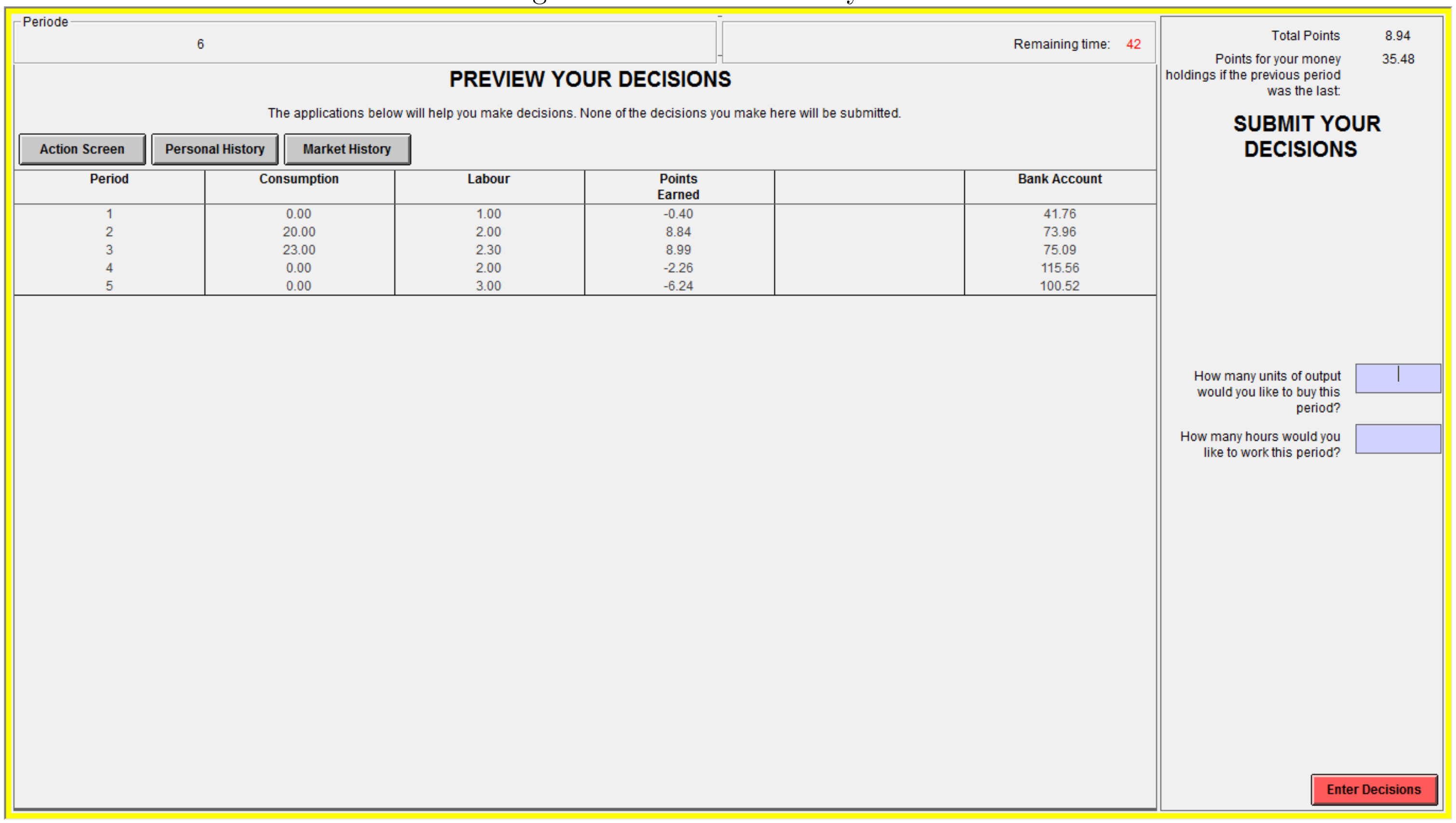
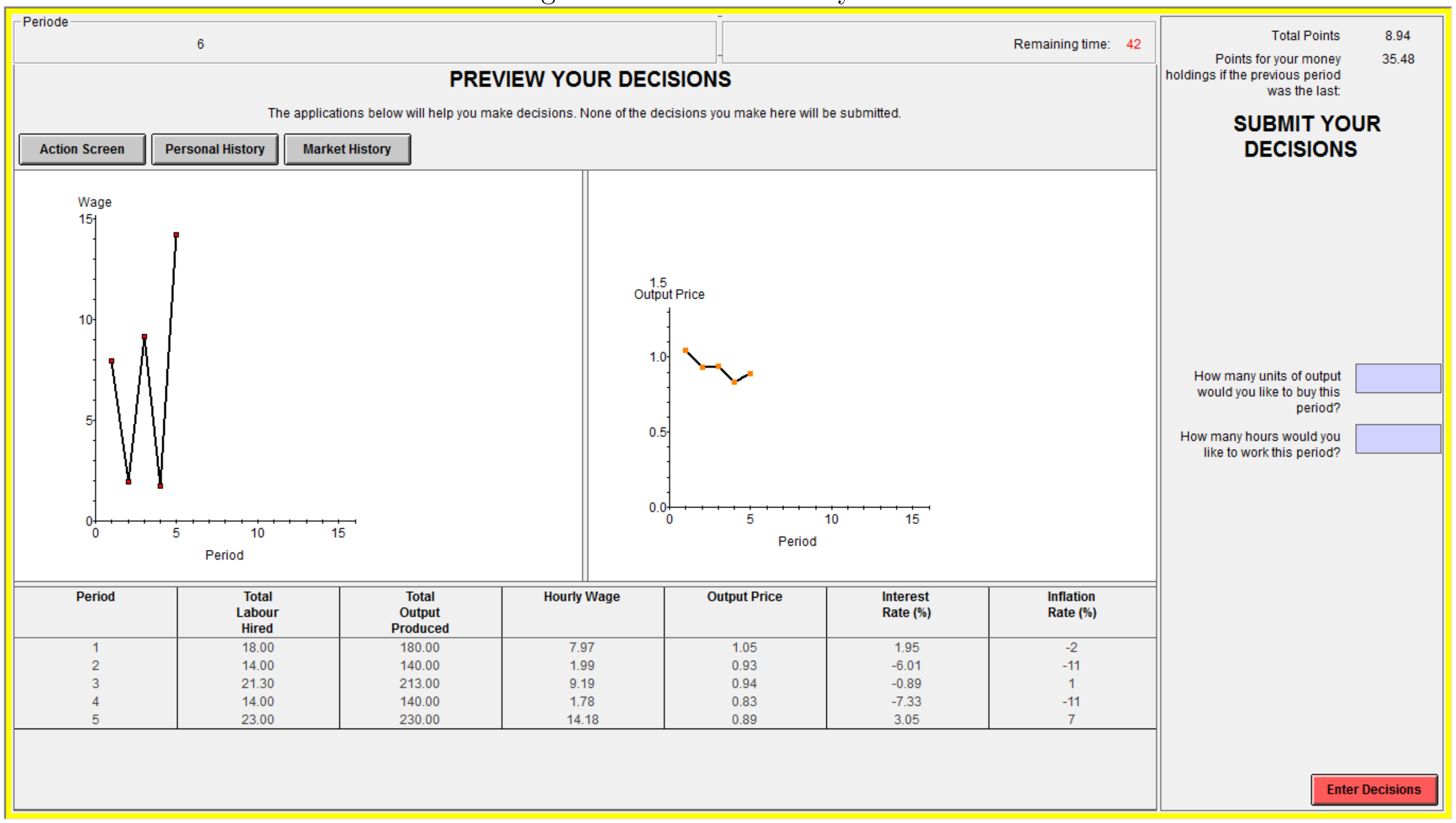


Figure 5: Personal history screen



Period	Consumption	Labour	Points Earned		Bank Account
1	0.00	1.00	-0.40		41.76
2	20.00	2.00	8.84		73.96
3	23.00	2.30	8.99		75.09
4	0.00	2.00	-2.26		115.56
5	0.00	3.00	-6.24		100.52

Figure 6: Market history screen



G Instructions

The instructions distributed to subjects in all the treatments (Random, Equitable, and Priority) are reproduced on the following pages. Subjects received identical instructions with the exception of the tables in Appendix F.

INTRODUCTION

You are participating in an economics experiment at the University of British Columbia. The purpose of this experiment is to analyze decision making in experimental markets. If you read these instructions carefully and make appropriate decisions, you may earn a considerable amount of money. At the end of the experiment all the money you earned will be immediately paid out in cash.

Each participant is paid 5 CAD for attending. During the experiment your income will not be calculated in dollars, but in points. All points earned throughout this game will be converted into CAD by applying the exchange rates found on the whiteboard.

During the experiment you are not allowed to communicate with any other participant. If you have any questions, the experimenter(s) will be glad to answer them. If you do not follow these instructions you will be excluded from the experiment and deprived of all payments aside from the minimum payment of 5 CAD for attending.

You will play the role of a household over a sequence of several periods (trading days). You will be interacting with other human consumers. There will be also computerized firms and a central bank operating in this experimental economy.

In this experiment, you will have the opportunity to work and purchase output in two markets. All transactions in all markets will be conducted using laboratory money.

OVERVIEW

The objective of each player is to make as many points as possible. You will receive points for purchasing more units of output in your bank account. You will lose points by working. You may borrow and save at the current interest rate.

LABOR & OUTPUT MARKETS

At the top of the screen you'll see a graph representing the different combinations of output (x-axis) and labor (y-axis) you can choose. Each of the different combinations defines:

- A current hourly wage
- A current price for a single unit of output

This information will be located on the right hand side of the graph. Notice that these 2 pieces of information are only potential outcomes. The actual outcomes will be computed based on everyone's actual choices.
You may agree to trade none, some or all of your labor hours to firms in exchange for potential wage. You will input the very <u>maximum</u> you would like to work. You may end up working less than your desired amount, but you will never work more than that. You are able to work a maximum of 10 hours per period and may also work fractions of an hour, up to 1 decimal place. eg. 4.3 or 7.2 hours. Each worker is able to produce 10 units per hour and this will never change. Wage income will be deposited from your bank account.

You may also choose to purchase output. You will input the very <u>maximum</u> you would like to purchase. You may end up purchasing less than your desired amount. Spending on output will be debited from your bank account. You will also receive a dividend from firms that will also help you to pay for the varieties you will purchase. This is an equal share of the positive or negative profits the firms earned in the current period.

To better understand how your labor and consumption decisions translate into points and how the balance on your bank account changes, you will have the opportunity to move the red dot to your preferred point on the payoff space. Notice that as you increase the amount of labor, you will lose points at an increasing rate. As you increase the amount of output, you will gain points at a decreasing rate.

Actual wage, output price and the interest rate will be computed based on your choices and everyone else's choices. That's why you will be able to move around 2 different dots, the red one that represents your own decisions and the green one that characterizes the average of everyone else's choices. This way you will visualize different predictions on wages and prices for different combinations of aggregate consumption and aggregate labor.

** You will have an initial balance of 10 experimental units of money on your bank account. Whenever your bank account is negative, ie. you spent more than you earned, you will owe the bank the remainder PLUS interest in the next period. So long as you pay the interest on your debt, you may continue to borrow. Any money owing at the end of the experiment will be repaid through points. In particular, you will lose: $\frac{1}{2.5} * \left(\frac{Bank\ Account}{10 * Output\ Price}\right)^{2.5}$. Similarly, If your bank account has a positive balance at the end of the experiment you will gain: $\frac{1}{0.67} * \left(\frac{Bank\ Account}{Output\ Price}\right)^{0.67}$.

**If your bank account is positive, you will receive interest on the saving in your bank account. This will be credited to your account in the next period.

After all subjects submit their labor, consumption, and investment decisions, firms will decide how many hours to hire. Wage and output price will be computed. There will be no unsold output. If the total number of labor hours supplied in the economy is in excess of what is necessary to satisfy consumers' output demands, firms will hire fewer hours and you may find yourself working a fraction of the hours you requested. Similarly, if the worker supplied hours is insufficient to cover consumer demand, you may find yourself able to purchase only a fraction of the output you requested.

As you purchase more units, you will gain more points but at a decreasing rate. As you work more hours, you will lose more points at an increasing rate. You do NOT obtain points from your holdings of cash.

Worker Points = (Points Gained from Consuming – Points Lost from Working)

The interest rate at which you spend or save will depend on inflation. Particularly, for every 1% that prices increase from yesterday, the automated central bank will increase the borrowing and saving rate by more than 1%. Over the long run, the central bank will aim to keep the interest rate around 3.5%, but it will fluctuate as inflation on output occurs. Lower interest rates make it cheaper to borrow but more challenging to accumulate savings, and vice versa.
Notice that interest rate might also be negative. In that case you will lose money by saving and gain money by borrowing.

Each sequence will have a random number of periods determined by a continuation rate of 0.965. That is, there is a 3.5% chance of a period ending at any period. To make the termination rule as transparent as possible, the experimenter will carry a bag containing 200 marbles, 193 of them are blue and only 7 of them are green. Each period a marble will be drawn. If a blue marble is drawn the sequence will end, otherwise the sequence will continue. You will play multiple sequences. On average you will play 28 periods in each sequence.

Screens

Throughout the experiment you will have a chance to flip back and forth between 4 different screens:

1) **Action Screen**. - This is the main screen. This screen is divided in two:

   a) On the left hand side of the screen you'll find a graph that represents all possible combinations of *labor and output*. On the graph you'll see two different dots. The red one represents your own choices. By moving around the red dot you will be able to visualize the points you might earn by selecting different combinations of *labor and output*.
   The green dot denotes the average values of *output and labor* of the rest of the participants. By moving around both dots you'll have a better sense on how your choices as well as everyone else's decisions affect the potential wage and output price of the economy. Your predicted banking account balance (without interest rate) will be also displayed.
   Notice that by positioning the dots together you will be assuming that everyone else's choices are the same as yours.

   b) On the right hand side of the screen (SUBMIT YOUR DECISIONS) you will have to enter your final choices on *output* and *labor.* Immediately after everyone submits their decisions, the total amount of output and labor will be computed.

2) **Personal History**.- You will find a summary of your previous decisions on *consumption, labor*, as well as the *points* you earned and your *bank account* balance.

3) **Market History**. - On this screen you will be able to observe information on *interest rates* and *inflation rate* from previous periods. Information on total *output and labor* is also included.

Some useful information

$$Points = \frac{1}{0.67} * (Output)^{0.67} - \frac{1}{2.5} * (Labour)^{2.5}$$

$$Steady\ State\ Output = 22.37$$

$$Steady\ State\ Labour = 2.24$$

H Specific Examples of the Rationing Rules

In addition to the instructions in Appendix G we showed subjects specific examples of how output and labor were allocated when there was rationing. The first table shows an example of rationing under excess output demand and the second table shows an example of rationing under excess labor supply for the Random, Equitable, and Priority treatments, respectively.

Allocation Rule

Output Produced= 10 × Hours of Work

Example of Excess Output Demand

Subject	Requested hours of work	Requested output	Assigned hours of work	Assigned output	
1	4	30	4	30	*(2nd spot)*
2	8	50	8	0	*(4th spot)*
3	4	100	4	100	*(1st spot)*
4	1	80	1	40	*(3rd spot)*
Total	17	260	17	**170**	

Output Produced= 17 × 10=170

Allocation Rule

Output Produced$= 10 \times$ Hours of Work

Example of Excess Labor Supply

Subject	Requested hours of work	Requested output	Assigned hours of work	Assigned output
1	7	30	4 *(3rd spot)*	30
2	8	40	8 *(1st spot)*	40
3	3	50	0 *(4th spot)*	50
4	1	10	1 *(2nd spot)*	10
Total	19	130	**13**	130

Hours of Work Hired$= \frac{130}{10} = 13$

Allocation Rule

Output Produced= $10 \times$ Hours of Work

Example of Excess Output Demand

Subject	Requested Hours of Work	Requested Output	Assigned Hours of Work	Assigned Output	
1	3	10	3	10	$\Rightarrow \min(10, 30)$
2	6	20	6	20	$\Rightarrow \min(20, 30)$
3	2	100	2	30	$\Rightarrow +15 = 45$
4	1	80	1	30	$\Rightarrow +15 = 45$
Total	12	260	12	90	**120**

Output Produced= 10×12=120

Average Output= $\frac{120}{4}$=30

Output Left= 120-90=30

Allocation Rule

Output Produced= 10 × Hours of Work

Example of Excess Labor Supply

Subject	Requested Output	Requested Hours of Work	Assigned Output	Assigned Hours of Work	
1	10	10	10	4	⇨ $+1.5 = 5.5$
2	15	7	15	4	⇨ $+1.5 = 5.5$
3	100	3	100	3	⇨ $\min(3, 4)$
4	35	2	35	2	⇨ $\min(2, 4)$
Total	160	22	160	13	**16**

Hours of Work Hired= $\frac{160}{10} = 16$

Average Hours= $\frac{16}{4}$=4

Hours Left= 16-13=3

Allocation Rule

Output Produced= 10 × Hours of Work

Example of Excess Output Demand

Subject	Requested hours of work	Requested output	Assigned hours of work	Assigned output	
1	4	30	4	30	
2	8	50	8	50	
3	4	100	4	40	+ [0,40]
4	1	80	1	10	+ [0,40]
Total	17	260	17	130	**170**

Output Produced= 17 × 10=170   Output Left= 170-130=40

Allocation Rule

Output Produced= $10 \times$ Hours of Work

Example of Excess Labor Supply

Subject	Requested hours of work	Requested output	Assigned hours of work	Assigned output
1	7	30	3 +[0,2]	30
2	8	40	4 +[0,2]	40
3	3	50	3	50
4	1	10	1	10
Total	19	130	11 **13**	130

Hours of Work Hired= $\frac{130}{10} = 13$

Hours Left= 13-11=2

References

CALVO, G. (1983): "Staggered Prices in a Utility Maximizing Framework," *Journal of Monetary Economics*, 12, 383–98.