Why labor supply is a substitute for saving and whether this explains precautionary behavior

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February 15, 2018
PRELIMINARY VERSION
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Abstract

We uncover a novel behavioral strategy that makes intertemporal substitution possible even if saving is not possible: Starting from the standard model of intertemporal substitution in consumption and labor supply (e.g. Low 2005 or Flodén 2006), we relax the strong assumption that wage changes coincide with the periodicity of labor supply. In our extended model, if wage risk is time-varying and work-time allocation is endogenous, subjects may allocate time differentially to work-shifts as a form of intertemporal substitution. In order to test our model, we conduct laboratory experiments. In four treatments, subjects can either save, allocate time, engage in both, or do neither. The results show that subjects engage in both precautionary saving and precautionary labor supply, as predicted. Subjects also regard these behavioral strategies as substitutes, though substitution is not perfect.

Keywords Intertemporal substitution, precautionary saving, precautionary labor supply, work-shift allocation, prudence, experiment

JEL Classification C91 · D91 · J22

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1 Introduction

It is a well-known fact that labor supply can be transformed into consumption *intra*temporally. But are savings and labor supply substitutes *inter*temporally? If so, intertemporal substitution is possible via labor supply or savings, while in the standard model, intertemporal substitution works via savings only. This paper formulates a simple extension to the standard model that allows one to determine the shift-specific average wage by choosing the length of the work shift endogenously. If this behavioral channel is important—as our results from laboratory experiments show—it may explain empirical puzzles in the literature on precautionary saving and labor supply. It provides one explanation for why standard saving regressions using survey data have provided mixed evidence on the importance of precautionary saving. Moreover, negative wage elasticities can be explained with our model, since an increase in a wage may change the optimal allocation of work-shifts.[1]

A main feature of our model is that we redefine labor supply. Because of measurement issues, various important studies treat labor supply as synonymous with effort at work and time spent working (Heckman 1993). However, Marshall (1920) notes that *"for even if the number of hours [of work] in the year were rigidly fixed, which it is not, the intensity of work would remain elastic"* (p. 438). In line with this insight, we allow distinct choice for effort and work-shifts.

Our results show that the model predicts behavior very well on the aggregate level. In particular, we show that work-shift choice, referred to as shifting, is equivalent to saving, though not for all subjects. We find that precautionary saving exists for 82% to 94% of subjects and precautionary shifting exists for 40% to 66% of subjects. We expect shifting behavior to be most relevant for short-term intertemporal substitution outside the lab and particularly important when saving is not possible. Examples include self-employed individuals in the gig economy, such as taxi drivers and artists. If such a worker becomes over-indebted, e.g. due to tuition fees, gambling, etc., shifting still allows the transfer of value through time. Since wages in these industries can be very volatile, shifting may be used as for precautionary reasons.

Precautionary saving is usually defined as the difference between consumption in the presence of risk and under perfect foresight. Some empirical evidence from survey data shows this

[1] Dickinson (1999) sets up a related model where workers can substitute on- and off-the-job leisure and tests it in experiments. In one of the conducted treatments, the subjects are only allowed to choose their effort (while work hours are fixed), and in another, they are also allowed to leave the experiment early. In both treatments the piece-rate for the real effort-task is varied within-subject. The results confirm the predictions of the model: subjects in the lab experiments substituted leisure on- and off-the-job, which explains the negative substitution effects.

kind of precautionary behavior may be economically important. Gourinchas and Parker (2002) attribute 60-70% of wealth to precautionary saving in early life. Kazarosian (1997) and Carroll and Samwick (1998) estimate the precautionary component of wealth to be in the range of 20-50%. However, the evidence is not unambiguous. With subjective earnings uncertainty, Guiso et al. (1992) estimate the precautionary component of wealth at only a few percentage points. Lusardi (1998, 1997) and Engen and Gruber (2001) find small precautionary wealth as well. Hurst et al. (2010) and Fossen and Rostam-Afschar (2013) argue that estimates are sensitive to whether business owners are included in the dataset.

Some of the problems in survey data may be avoided in experimental settings, but the experimental literature on precautionary saving is relatively small. Fuchs-Schündeln and Schündeln (2005) show that, in accord with a model that includes substantial precautionary effects, saving rates of most East Germans increased sharply after the natural experiment of the German unification, but saving rates of civil servants did not. By contrast, West Germans—who would have been subject to more selection into jobs based on risk preferences—exhibited little difference in saving rates between civil servants and others with riskier jobs, either before or after reunification. Meissner and Rostam-Afschar (2017) show that in a controlled laboratory environment more than 50% of subjects simplify consumption decisions by ignoring incentives for precautionary behavior. Ballinger et al. (2003) study precautionary saving and social learning. They find that subjects save too little early in the life cycle. Still, the qualitative features of behavior are corroborated in their experiment, even if it misses the point predictions of the standard model with precautionary motives. Brown et al. (2009) tests two explanations for apparent undersaving in life-cycle models: bounded rationality and a preference for immediacy.

With flexible hours of work a second channel emerges through which individuals may react in a forward-looking way: Individuals may take into account their expectation about future wage risk when deciding how much to work in a given period (see Flodén (2006) or Low 2005 for a model and simulations). Individuals with higher risk, e.g. self-employed, would work longer *before* shocks are realized to accumulate precautionary wealth. Precautionary labor supply is then defined as the difference between hours supplied in the presence of risk compared to certainty.

On the empirical side, very little research has been devoted to precautionary labor supply. As reported by Mulligan (1998), "there is no empirical evidence that precautionary motives for delaying leisure are important" (p. 1034). Pistaferri (2003) finds that the effect of wage risk on labor supply is in agreement with the theory, but in practice negligible. Jessen et al. (2017) find that the self-employed would work 4.5% less if they faced the same wage uncertainty as the median civil servant. In this paper, we redefine labor supply as a function of two endogenous choices: effort and work-shift allocation (shifting). Therefore, we define precautionary shifting as the difference in the length of a work-shift under risk and without risk.

While we focus on this channel of intertemporal substitution, Eeckhoudt et al. (2012) and Wang and Li (2015) recognized that precautionary saving may result from precautionary effort, a third channel. They show that precautionary saving and precautionary effort are implied by prudence alone. We define precautionary effort in a slightly different manner as the difference between effort costs under risk and under perfect foresight. This third channel of precautionary behavior has only been indirectly addressed by Huck et al. (2017). In their experiments, subjects work on a task and information about the uncertain piece-rate is either (i) shown (resolving the uncertainty); (ii) not shown (subjects work without knowing which of the two possible piece-rates is applied); and (iii) subjects can choose whether they would like to learn the piece-rate or not. Information avoiders in the last treatment (about a third of the subjects) outperform the information seekers.

The aim of our paper is to disentangle the behavioral implications of each of the previously described three channels in one experimental setting. The paper is structured in the following way: Section 2 presents our extension of the standard model of consumption and labor supply and our behavioral hypotheses, Section 3 describes our experimental design and procedures, and Section 4 presents and discusses our findings. Finally, Section 5 summarizes and concludes.

2 A Simple Two Period Model

We propose a model of intertemporal choice that deviates in three aspects from the standard model of consumption and labor supply (e.g. Flodén 2006): the margin of intertemporal choice, heterogeneity in productivity, and the specification of the valuation.[2] To this end, we redefine labor supply as a function of two endogenous variables, namely supply of effort and supply of work-shift time.

Definition 1 – *Supply of Effort: Effort is total cost incurred during given duration.*

[2] We build on insights on intertemporal choices from standard labor supply models in Heckman and MaCurdy (1980), MaCurdy (1981), and Blundell and Walker (1986) and in particular on the precautionary labor supply model analyzed in Flodén (2006). See Card (1994), Blundell and MaCurdy (1999), and Keane (2011) for surveys.

Definition 2 – *Supply of Work-Shift Time: A work-shift is calendar time spent working with continuous effort. Work-shift ends with valuation of total work net of total effort costs accumulated during work-shift.*

Most importantly, our model generalizes the standard model by allowing the time span underlying intertemporal choices to differ from the periodicity of the decision environment. This is necessary to measure precautionary behavior through time allocation, which requires keeping the decision environment exogenous.

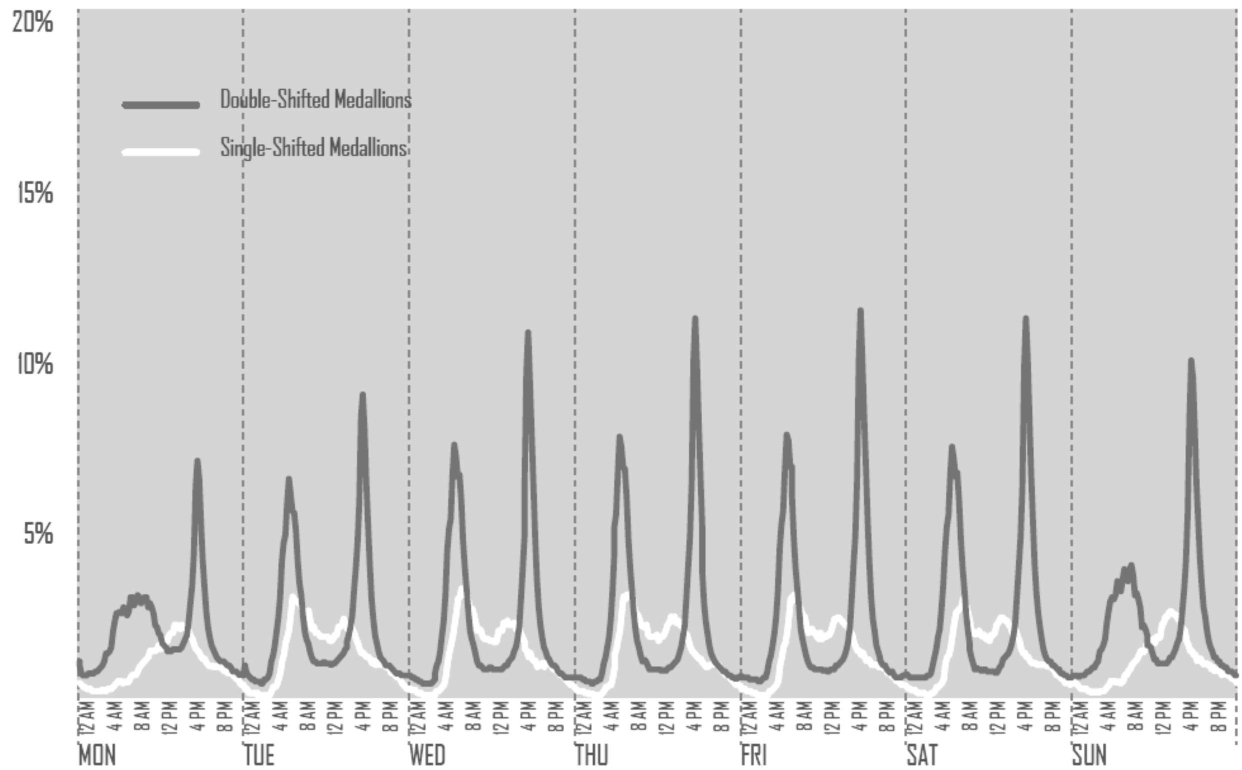


Figure 1: Percentage of Shifts Started by Time of Day (15-Minute Increments)
Source: New York City Taxi & Limousine Commission (2014), Trip-sheet data.

While the definition of effort supply is intuitive, how it matters if work-shifts are chosen endogenously needs closer investigation. A simple example assuming constant effort costs illustrates this. The exogenous periodicity is the 'morning' and 'evening' of a twelve-hour work day. The endogenous periodicity is 'work-shifts' during this twelve-hour work day. Suppose a New York City taxi driver earns $26.50 per hour in the morning (from 11 a.m. to 5 p.m.) and $40 in the evening (from 5 p.m. to 10 p.m.).[3] The standard model would imply that the end of the first work-shift co-

[3] Exact figures of this real-world example can be found in New York City Taxi & Limousine Commission (2014).

incides exactly with the change in the hourly wage. In practice, such a case could be the effect of regulations. For instance, if our taxi driver was licensed by the New York City Taxi and Limousine Commission, she was required to operate in two shifts each day before 2015 (see double-shifted medallions in Figure 1). Given such a regulation, she could consider becoming, say, an Uber or Lyft driver instead, thus enabling her to choose when to finish her work-shift and, for example, drive the 12 hours straight. Now suppose she had to pay a fee to the cab office depending on her total income in a work-shift. Consider a pricing policy that states that she has to pay 25% if her income is above $200 and 20% otherwise. This describes the basic setting that we use to investigate choices in this study.

In this situation, our taxi driver comes to the conclusion that it would be best to work a first shift for about seven hours and a second for five hours to avoid paying the higher fee. While the incentives are obvious in this simple example, in reality the fact that the hourly wage is often unknown ex-ante may lead to interesting behavior. In fact, when starting the work day, a taxi driver could expect a gross hourly income that is close to certain in the morning shift but that is much more volatile in the second shift because extreme events such as a very slow or a very busy night might occur. We introduce uncertainty about the second-period income in order to derive clear predictions that we subsequently test in our experiments.[4]

2.1 A general model of intertemporal substitution

Now consider a simple two-period model with two work-shifts, where ex-ante total consumption C is the sum of consumption in work-shift 1, c_1, and expected consumption in work-shift 2, $E[c_2]$. In both work-shifts $i = 1,2$, consumption is a concave function of income $c(y_i)$ which can be interpreted as a progressive tax. The subjects' problem is

$$\max_{y_1,y_2} C = c(y_1) + E_\varepsilon[c(y_2)]. \tag{1}$$

Work-shift specific income, in turn, depends on exogenously given period-specific wage rates w_j with periods $j = 1,2$ and three kinds of shift-specific choices: effort e, saving s, and choice of

[4] Our model also applies to cases where the wage changes occur not through time but concurrently, as long as the certain and the uncertain components can be separately related to work-shift allocations. For instance, consider bonus payment schemes, where on top of a fixed wage, a payment may be realized that varies with uncertain outcomes like annual revenues or the current stock price of a company. It is fairly straightforward to extend our model to a case in which the probability of receiving a bonus payment depends on one's productivity.

the relative length of the first work-shift $t \in [0,1]$ (accordingly, the second shift's relative length is $1-t$). Both periods' absolute length is exogenously fixed and lasts T units of time. For simplicity and without loss of generality, we assume that each of the two periods takes $0.5 \times T$ units of time. At the beginning of the second period, the period-specific wage rate $w_{i=1}$ changes exogenously to w_2. The first-period wage rate is certain, $w_1 = w$, while the second-period wage rate w_2 is uncertain. In the second period, a wage shock ε shifts $w_2 = w + \varepsilon$. It is important to emphasize that the occurrence of the wage shock is only revealed after all decisions have been made. This makes it possible to isolate the effects of uncertainty. Furthermore, this represents a direct implementation of the models described in Flodén (2006), Parker et al. (2005), Hartwick (2000), and Eaton and Rosen (1980). This design feature is often an element of real-world settings. For example, to obtain a bonus payment, it might be necessary to allocate effort before the particular amount of payment is known.

The choice of t causes income y_i in each shift to be determined by wage of period $i = j$ or wages of both $i = j$ and $i \neq j$.

In particular, income in shift 1 is

$$y_1 = \begin{cases} y_1(t, w_1, e_1, s) & \text{if } t < 0.5 \\ y_1(0.5, w_1, e_1, s) & \text{if } t = 0.5 \\ y_1(t, w_1, e_1, w_2, e_2, s) & \text{if } t > 0.5 \end{cases} \tag{2}$$

and income in shift 2 is

$$y_2 = \begin{cases} y_2(t, w_1, e_1, w_2, e_2, s) & \text{if } t < 0.5 \\ y_2(0.5, w_2, e_2, s) & \text{if } t = 0.5 \\ y_2(t, w_2, e_2, s) & \text{if } t > 0.5. \end{cases} \tag{3}$$

This shows that by different choices of t, different period wage rates determine the shift-specific income in the generalized model and that $t = 0.5$ nests the standard model as a special case.

Figures 2 and 3 illustrate this. In the standard model, labor supply is chosen according to only one wage prevalent in a given period. This, of course, is a simplification of reality, as hours of work are often chosen before wages are realized and the expected wage may inform allocation decisions. However, this set-up precludes the possibility of influencing the expected wage by choosing how long a work-shift is. Consider again the New York City taxi driver to see how strong

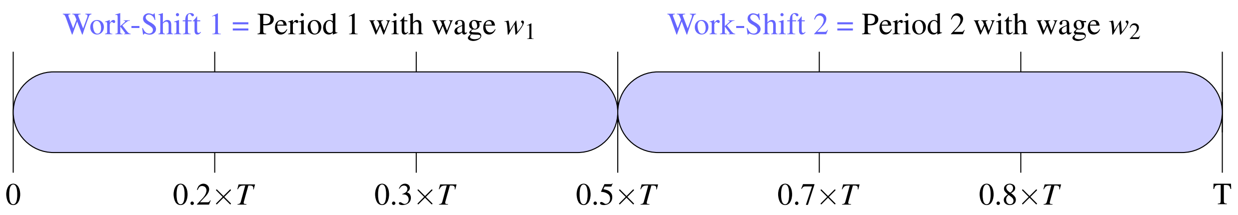


Figure 2: Labor Supply and Wage Changes in the Standard Model

Source: Authors' presentation.

this assumption is. In the example there are two periods of six hours each, i.e. $T = 12$ hours, with two average wages: $w_{j=1} = \$26.50$ in the morning and $w_{j=2} = \$40$ in the evening.

Fixing work-shifts means that the taxi driver has a time budget of six hours for the morning and six hours for the evening. Again, there is the fee of 25% if her work-shift income is above \$200 and 20% otherwise. In the standard model or under a double shift requirement, she could not exceed her time budget to work seven hours in a first shift; so to avoid the higher fee, she could work the six hours at the low wage w_1 in the morning and only five out of six hours at the high wage w_2 in the evening. Her net earnings would be $(1-0.2)[6 \times 26.50 + 5 \times 40] = \$287.20$ for 11 hours of work (out of a budget of 12 hours). The average hourly wage for the entire day would be \$26.11. A better option that is possible in the standard model would be to work six hours in the morning and six hours in the evening. This situation, in which she uses her entire time budget, is shown in Figure 2. She would earn $(1-0.2)[6 \times 26.50] + (1-0.25)[6 \times 40] = \$307.20$ for 12 hours of work. Since she could not avoid the higher fee, her hourly wage for the entire day would be \$25.60, and, hence, lower than in the first case.

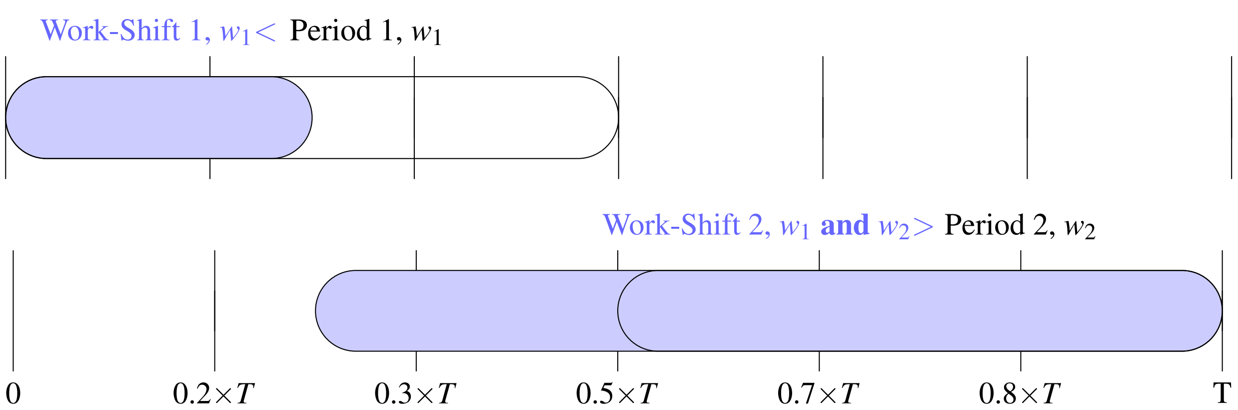


Figure 3: Labor Supply and Wage Changes in the General Model

Source: Authors' presentation.

If the taxi driver were free to choose her work-shift within the 12 hours day, she could influence the average hourly wage by finishing her first shift just after the first hour with the new wage of \$40, i.e. after seven hours at 6 p.m. In fact, the average wage for the first shift in the two cases just considered was always $w_{i=1} = w_{j=1} = \$26.50$, while the average wage in this case is $w_{i=1} = [6 \times 26.50 + 40]/7 = \$28.43 > w_{j=1}$. She could avoid paying the higher fee and earn a total of $(1-0.2)[7 \times 28.43 + 5 \times 40] = \$319.20$. The hourly wage for the entire day would be \$26.60, higher than in all other cases. The standard model would not only get the work hours per period wrong but also the total earnings.

Figure 3 shows an example of the opposite case, where it is better have an average of period wages in work-shift 2. The main point is that we generalize the standard model, which does not take into account that choice of labor supply may determine the hourly wage.

Precautionary motive The choice of t does not only change input factors to income but also determines which amount is evaluated in the concave consumption function $c(y_i)$. At the end of each work-shift, first savings are chosen and then a tax resulting in after-tax consumption c_i is imposed.

In each work-shift, after-tax consumption is related to income by a scaled and shifted isoelastic function

$$c(y_i) = \Big([1/(1-\tau)(y_i^{1-\tau} - 1)] - \eta \Big) \zeta. \tag{4}$$

In this specification, parameter τ determines the degree of risk aversion and prudence, and its reciprocal $1/\tau$ determines the intertemporal elasticity of substitution induced by the tax system.[5] This tax schedule leads to a positive third derivative (convex marginal net consumption). This is important for our analysis since optimal choices are affected by risk. The underlying mechanism is the tax function, which induces prudent behavior. Prudence is measured by the parameter of relative prudence (Flodén (2006); Kimball (1990)). This parameter in our case is $-y_i \frac{c'''}{c''} = 1 + \tau$. Accordingly, marginal after-tax consumption is higher when before-tax income is low, and the *rate* at which marginal after-tax consumption rises when before-tax income falls is greater when before-tax income is low than when it is high.

Given the precautionary motive, there are two choices that reflect precautionary behavior, both of which we will analyze separately and jointly. First, as in the standard model, prudent individuals

[5] The standard definition of a progressive tax function is that the marginal tax rate is larger than the average tax rate for every level of gross consumption. With our specific tax function the tax schedule is progressive from $y_i > exp(8)$ on, the relevant region in our experiment.

have an incentive to save in response to the anticipated wage risk. Insurance against wage risk is the only reason for saving in our experiment since the expected wage is identical in periods 1 and 2. The possibility to end a work-shift before or after a change in wage risk creates another route to engage in precautionary behavior: prudent individuals may, for example, have incentives to sacrifice some payoff and end the first shift before the wage becomes uncertain in order to make it more likely that they realize a specific payoff amount.

Budget constraint The second major difference to standard labor supply models is that we specify a function $c(y_i)$ that valuates benefits net of costs instead of the additive separable valuation of benefits and costs of work. Instead of describing the situation of employees, where disutility of work accrues privately (and is valuated in an additive separable way), in our model the costs of work can immediately be deducted as business expenses before valuation. This resembles the situation of self-employment more closely. While the main reason for this design feature is that the self-employment specification requires fewer non-linear functions, which makes the experimental setup simpler to explain, this disincentivizes precautionary effort, i.e. higher effort in the first work-shift under uncertainty than under certainty.

In particular (we present the other cases below), the shift-specific budget constraint y_i for the case $t = 0.5$ is given by

$$y_1 = w_1 \times q(e_1) - v(e_1) - s, \tag{5}$$

$$y_2 = w_2 \times q(e_2) - v(e_2) + s. \tag{6}$$

Income is the product of wage times production, which in turn is determined by effort, at the end of a work-shift. From this income, savings are deducted in the first work-shift and added in the second work-shift. Effort translates to a production quantity according to a production function $q(e_i)$ from which costs of effort $v(e_i)$ are deducted.

Production function We do not impose a production function in the experimental design. In line with Gächter et al. (2016), who introduced the experimental real effort task, our aim is to estimate the production function from the experimental data. As Gächter et al. (2016), we will estimate a production function of the form

$$q(e_i) = \beta_1 (e_i)^{0.5} + \beta_2 (e_i)^2 + \gamma, \tag{7}$$

where γ is fixed production, i.e. effortless output. As our predictions depend on the production function, we will estimate the form of the production function in the first subsection of our results.

Cost function and final payoff We specify a quadratic cost function for effort that limits the optimal level of effort, where we round costs to the next integer. Moreover, the quadratic cost function resembles fatigue effects with increasing effort frequently specified in the labor supply literature (cf. Moffitt 1984).

$$v(e_i) = \sum_{j=0}^{i} \varphi \times e_j^2. \tag{8}$$

The final payoff for the subjects is given as the euro amount given by Equation (1) rounded to the second decimal place. This calibration is chosen to directly convert the experimental currency in euros for final payoff.

2.2 Treatments

Our objective is to test how subjects use the three different precautionary channels. To do this, we simplify the setup dramatically for the first treatment group and allow more choices in subsequent treatments, as shown in Table 1.

Table 1: Treatments and Choices

	Treatments			
	I	II	III	IV
Effort	Allowed	Allowed	Allowed	Allowed
Saving	Not Allowed	Allowed	Not Allowed	Allowed
Time Allocation	Not Allowed	Not Allowed	Allowed	Allowed
	Choices			
Effort	e_1, e_2	e_1, e_2	e_1, e_2	e_1, e_2
Saving		s		s
Time Allocation			t	t

Source: Authors' presentation.

Treatment I: Hand-to-Mouth In reality, many consumers lead a 'hand-to-mouth' existence: they simply consume their net income and do not save (Kaplan and Violante 2014). This may be due to unsophisticated behavior (non-optimizing, or 'rule-of-thumb' consumers), or due to inability to trade in asset markets because of infinitely high transactions costs.[6] In our experiment we restrict subjects in Treatment I to be hand-to-mouth consumers, i.e. $t = 0.5$ and $s = 0$. In this way we generate a 'control' treatment where intertemporal consumption smoothing is not possible. In this treatment the only effect of wage risk is to make the second period effort level lower than under perfect foresight (because of the tax function). However, this treatment also allows us to measure the unconfounded production function of subjects for a single period.

To find the optimal effort, a Lagrange function $\mathscr{L}^I$ for Treatment I can be written for each work-shift i as

$$\mathscr{L}_i^I = E_\varepsilon[c(y_i, e_i)] + \mu^I(E_\varepsilon[w_i \times q(e_i) - v(e_i) - y_i]),$$

where the expectation operator is only relevant for work-shift $i = 2$. As the two work-shifts are not connected via savings or time-allocation, each optimization can be considered separately. In each work-shift, the only choice variable in this setting is effort e_i.

The first order conditions are (with partial derivatives denoted as $c_{y_i} = \frac{\partial c(y_i,e_i)}{\partial y_i}$, e.g. and the Lagrange multiplier for treatment k as μ^k)

$$\begin{aligned} \frac{\partial \mathscr{L}_i^I}{\partial y_i} &= E_\varepsilon[c_{y_i}] - \mu^I = 0, \\ \frac{\partial \mathscr{L}_i^I}{\partial e_i} &= E_\varepsilon[c_{e_i}] + \mu^I(E_\varepsilon[w_i q_{e_i} - v_{e_i}]) = 0. \end{aligned}$$

Income and effort can then be traded at a rate equal to the difference between valued marginal production and marginal costs.

$$E_\varepsilon[c_{y_i}(w_i q_{e_i} - v_{e_i})] = -E_\varepsilon[c_{e_i}]. \tag{9}$$

Some examples illustrate this: Example 1. Suppose $c(y_i, e_i) = 4(y_i - 8) - 40e_i$, i.e. e_i appears in $c(y_i, e_i)$ as in the standard model, $y_i = E_\varepsilon[w_i]q(e_i) - v(e_i)$, $q(e_i) = e_i$, and $v(e_i) = e_i^2$. Then $c_{y_i} = 4$, $q_{e_i} = 1$, $v_{e_i} = 2e_i$, and $c_{e_i} = c_{y_i} q_{e_i} = -40$. Using these values gives us $c_{e_1} = 4(w_1 - 2e_1) = 40$ for the first work-shift, so if $w_1 = 100$ then $e_1 = 45$. Consider the same specification for the second period, where $w_2 = 20$ or 180 with probability $p = 0.5$. Then $4(E_{80}[w] - 2e_2) = 40$, so $e_2 = 45$. Risk has no effect on the optimal choice of effort.

Example 2. Now suppose $c(y_i) = 4(y_i - 8)$, i.e. e_i determines y_i but $c(y_i)$ can be written without e_i, $y_i = E_\varepsilon[w_i]q(e_i) - v(e_i)$, $q(e_i) = e_i$, and $v(e_i) = 0.5e_i^2$. Then $c_{y_i} = 4$, $q_{e_i} = 1$, $v_{e_i} = e_i$,

[6] This corresponds to the static model discussed in section 3.1 in Keane (2011).

and $c_{e_i} = c_{y_i} q_{e_i} = 0$. For the first work-shift, we obtain $4(w_1 - e_1) = 0$, so $w_1 = 100$, $e_1 = 100$, $e_2 = 100$ and again risk does not matter in both work-shifts. If $c(y_i)$ becomes the log function $c(y_i) = 4(E_\varepsilon[\log(y_i)] - 7)$, $c_{y_i} = E_\varepsilon[4/(y_i - 7)] = E_\varepsilon[4/(w_i e_i - 0.5e_i^2 - 7)]$ and thus, under certainty, again $(w_1 - e_1) = 0$. By contrast, in the second period, $0.5c_{y_i}(20q_{e_i} - v_{e_i}) + (1 - 0.5)c_{y_i}(180q_{e_i} - v_{e_i}) = \frac{2(20-e_2)}{20e_2-0.5e_2^2} + \frac{2(180-e_2)}{180e_2-0.5e_2^2} = 0$, so $e_2 = 26.31$. This is an instantaneous effect of risk, not a reaction to anticipated risk in the second work-shift, because intertemporal substitution is not allowed in this treatment.

With the first order condition and the production function (which will be estimated in Section 4), we can derive optimal levels of effort. Given our experimental setting, we can test the following hypothesis:

Hypothesis 1 (Direct reduction of effort by risk): *With valuation of income as a concave function, optimal effort will be smaller under uncertainty than under certainty, i.e. effort will be smaller in the second work-shift than in the first work-shift.*

Treatment II: Precautionary Saving While hand-to-mouth behavior can be observed in many situations, another important behavioral tendency is to 'save for a rainy day'. This understanding of precautionary behavior has received much attention in the literature, although, as mentioned before, the empirical evidence for it is mixed. The main purpose of Treatment II is to shed light on whether precautionary saving occurs at all. In each work-shift, the choice variable is effort e_i and at the end of the first work-shift the amount of savings s is chosen.

By allowing that subjects save at the end of the first period (but not borrow), the Lagrange function $\mathscr{L}^{II}$ for determining optimal effort changes only slightly compared to Treatment I: The intertemporal budget, not the intratemporal, constrains choices (see Equations (5) and (6)). Ex-ante, the sum of the net payoff from both periods is relevant. Abstracting from the borrowing constraint, $\mathscr{L}^{II}$ can be written as

$$\mathscr{L}^{II} = c(y_1, e_1) + E_\varepsilon[c(y_2, e_2)] + \mu^{II}(E_\varepsilon[w_1 \times q(e_2) + w_2 \times q(e_2) - v(e_1) - v(e_2) - y_1 - y_2]).$$

Compared to Treatment I, optimal behavior is subject to one more necessary condition, namely the net income Euler equation:

$$c_{y_1} = E_\varepsilon[c_{y_2}], \tag{10}$$

$$E_\varepsilon[c_{y_i}(w_i q_{e_i} - v_{e_i})] = -E_\varepsilon[c_{e_i}]. \tag{11}$$

In the absence of risk, the intertemporal condition ensures that the net payoff in both periods will be smoothed. In our application, the expected wage in the second period is identical to the certain wage in the first period. Therefore, given productivity and effort, there is no reason for a difference in net payoffs in both periods except for precautionary cuts of first-period income, i.e. $y_1(s > 0) < y_1(s = 0)$. This shows that not to save reduces payoffs.

Reconsidering Example 2 from above, there are two things to note: First, under certainty, savings will be zero, but under uncertainty there is a strictly positive amount of savings. This shows that of the many reasons to save enumerated by Browning and Lusardi (1996), the precautionary motive is the only determinant of all savings. Second, if the third derivative of $c(y_i)$ is not positive, like in the case of $c(y_i) = 4(y_i - 8)$, where net work-shift payoff is linear in gross income, (precautionary) saving will be zero: $c_{y_1} = E_\varepsilon[c_{y_2}] = c_{E_\varepsilon[y_2]}$, such that $e_1 = e_2$ and $c(y_1, e_1) = c(y_2, e_2)$.

Hypothesis 2 – Precautionary saving and effort: *i. Existence of precautionary motive: In anticipation of risk in the second period, a strictly positive fraction of income will be saved.*
ii. Absence of precautionary effort: These savings do not result from increased effort in the first work-shift, which will be the same as under certainty and as in Treatment I, but from a deduction in the payoff relevant income in the first work-shift.
iii. Smaller effort without intertemporal substitution: With valuation of income as a concave function, optimal effort will be smaller under uncertainty than under certainty, i.e. effort will be smaller in the second work-shift than in the first work-shift. The difference between effort in both periods will be smaller in Treatment II than in Treatment I due to savings.

Treatment III: Precautionary Shifting While precautionary behavior through savings is a well-known concept, another option for shifting income intertemporally has been overlooked to date: precautionary time allocation. To the best of our knowledge, we are the first to consider this alternative mechanism. As the example of New York City taxi driver shows, storing value to transfer it intertemporally might be inconvenient or impossible, especially when the frequency considered is within a short period like a single day. For instance, think of a highly indebted taxi driver who may keep a fraction of income for living expenses, fuel, and repairs, but must use all other income to pay off debts. We show how this taxi driver may substitute intertemporally, though she cannot save: value can be transferred intertemporally based on the periodicity of exogenous movements and the option of dividing a specific time span into work-shifts.

To study this mechanism, we change two particular features in the setup for Treatment III compared to Treatment II. First, we do not allow saving anymore, i.e. $s = 0$. Second, we introduce the possibility to choose when work-shift 1 ends. This changes the budget constraints for each work-shift such that each has now three cases as shown in Equations (2) and (3).

The choice of t determines which of the three cases is relevant. If $t = 0.5$, the periodicity of wage change coincides with the work-shift change such that income in work-shift 1 depends on the effort and wage in period 1. Income in work-shift 2 depends on the effort and wage in period 2. If $t < 0.5$, work-shift 1 is shorter than work-shift 2. All income in work-shift 1 is determined by the effort and wage in period 1. However, income in work-shift 2 is determined by the effort and wage of both period 1 and 2. If $t > 0.5$ income in work-shift 1 is determined by the effort and wage of both periods, while income in work-shift 2 depends only on the effort and wage in period 2.

The task is to choose the length of work-shifts t and, in each work-shift, effort e_i. The Lagrange function is

$$
\begin{aligned}
\mathscr{L}^{III/IV} \quad = \quad & c(y_1,e_1) + E_\varepsilon[c(y_2,e_2)] + \mu^{III/IV}\Big\{ \qquad (12) \\
+\mathbb{1}_{\{t=0.5\}} \quad \times \quad & \Big[2\times t[w_1\times q(e_1) - v(e_1)] - y_1 \\
+ \quad & 2\times(1-t)E_\varepsilon[w_2\times q(e_2) - v(e_2)] - y_2\Big] \\
+\left(1-\mathbb{1}_{\{t=0.5\}}\right)\mathbb{1}_{\{t<0.5\}} \quad \times \quad & \Big[2\times t[w_1\times q(e_1) - v(e_1)] - y_1 \\
+ \quad & 2\times(0.5-t)[w_1\times q(e_1) - v(e_1)] \\
+ \quad & 2\times 0.5E_\varepsilon[w_2\times q(e_2) - v(e_2)] - y_2\Big] \\
+\left(1-\mathbb{1}_{\{t=0.5\}}\right)\left(1-\mathbb{1}_{\{t<0.5\}}\right) \quad \times \quad & \Big[2\times 0.5[w_1\times q(e_1) - v(e_1)] \\
+ \quad & 2\times(t-0.5)E_\varepsilon[w_2\times q(e_2) - v(e_2)] - y_1 \\
+ \quad & 2\times(1-t)E_\varepsilon[w_2\times q(e_2) - v(e_2)] - y_2\Big]\Big\},
\end{aligned}
$$

where $\mathbb{1}_{\{\text{condition}\}}$ is an indicator that equals 1 if the condition is true. Since our model is a two-period model, the time allocation refers to *two* times a period. This shows that compared to Treatment II, only the budget constraint looks different: instead of subtracting a specific amount of saving at the end of a period, the choice of the length of a work-shift determines how much is subtracted from income. Thus, the intertemporal optimality condition is identical in Treatments II and III. For an optimizing decision-maker, both options are substitutes for intertemporal substitution. In practice, however, behavior may vary depending on whether saving or time allocation is allowed.

$$c_{y_1} = E_{\varepsilon}[c_{y_2}], \tag{13}$$

$$c_{y_1}(w_1 q_{e_1} - v_{e_1}) = -c_{e_1}, \tag{14}$$

$$E_{\varepsilon}[c_{y_2}(w_2 q_{e_2} - v_{e_2})] = -E_{\varepsilon}[c_{e_2}]. \tag{15}$$

In the absence of risk, there is perfect smoothing, i.e. both period efforts will be identical, and t will be 0.5. Since intertemporal shifts can be achieved with the same costs as in Treatment II, under risk, both effort levels and the net payoff will be identical to that of Treatment II. Prudent decision-makers will find it optimal to finish work-shift 1 early in anticipation of the higher risk in the second period. The rate at which marginal after-tax payoff falls when before-tax income rises is greater when before-tax income is low than when it is high due to convexity of marginal after-tax payoff. Therefore, decision-makers will use the certain wage to build up a level of net payoff in order to avoid deep declines in payoff before working under the uncertain piece-rate begins.

Hypothesis 3 – Precautionary shifting: *i. Existence of precautionary shifting: Work-shift 1 is shorter than work-shift 2.*
ii. Identical choices with intertemporal substitution: Effort levels are identical to those of Treatments II and IV. The average payoff is identical to that of Treatments II and IV.

Treatment IV: Precautionary Shifting and Saving Of course, some self-employed may have the option of both determining when to finish a work-shift and whether to store value over time. Therefore, we consider the case where both saving and work-shift allocation is allowed. The budget constraints change slightly in comparison to Treatment III because savings s are not restricted to zero anymore and may be non-negative. The budget constraints are given in Equations (2) and (3). The Lagrange function and the optimality conditions, however, are identical to that of Treatment III (hence $\mathscr{L}^{III} = \mathscr{L}^{IV}$). This is because while savings enter the period budget constraints, they cancel out in the intertemporal budget constraint. Therefore, the resources on which the decisions are based remain unchanged.

Even though theoretically the decision problems of Treatment III and IV are identical, in practice, behavior could very well be different due to the nature of the respective saving mechanism: work-shift allocation decisions are more impulsive than saving decisions, since the end of a work-shift implies discontinuing working at once, while the saving decisions can take as long as the subjects prefer. In other words, work-shift allocation implies making a final choice without the opportunity to reconsider, while saving preferences can be reconsidered and changed. Accordingly, in this treatment, shifting and saving could be substitutes for intertemporal substitution in the sense that subjects try to find the optimal work-shift allocation and readjust their decisions using the savings channel, if they made a mistake. Therefore, one of the channels could be used more frequently than the other depending on optimization errors.

In the general setup of this analysis, labor supply and savings are in fact perfect substitutes. The comparison of Treatments II and III shows whether subjects can achieve the same expected payoff by choosing the right work-shift allocation and the right amount of savings, respectively. Treatment IV goes one step further to analyze whether subjects do not only substitute the extreme cases but also choose combinations of work-allocation and saving.

The objective of this treatment is to test whether subjects regard the two channels as the perfect substitutes theory predicts them to be. We can test the following hypothesis implied by the redundancy of saving.

Hypothesis 4 – Precautionary saving and shifting: *i. Either work-shift 1 is shorter than work-shift 2, or there are positive savings, or both. Since choosing savings after a work-shift and allocation of work-shifts are perfect substitutes, there is no systematic difference in the frequency of positive savings and shorter first period work-shifts.*
ii. Identical choices with intertemporal substitution: Effort levels are identical to those of Treatments II and III. The average payoff is identical to that of Treatments II and III.

3 Experimental Design and Procedures

Our experimental design follows our previously described model closely. In order to compare the decisions of all participants under all four treatments, we use a within-subject design for our individual decision-making experiments. Before we describe the different stages of the experiment, we explain the real-effort task that resembles work in our stylized labor market situations.

The task We use the ball-catching task proposed by Gächter et al. (2016). Figure 4 shows an example screen of this task. In the ball-catching task subjects are presented a rectangular box. There are balls hanging at the top of the box in four columns and a tray is positioned at the bottom of the box. As soon as subjects click the start button, balls fall down the screen in either one of the four columns at constant speed (probabilities are equal for the next ball to fall down in any column). Subjects earn the constant piece-rate w_j within period j by catching balls with the tray (hence, the expected work-shift revenue is equal to $R_i = q_1 \times w_1 + E\,(q_2 \times w_2)$ with q_j the number of caught balls in a period). In order to catch the balls the subjects can move the tray from one column to the other by clicking two buttons under the rectangular box labeled LEFT and RIGHT.

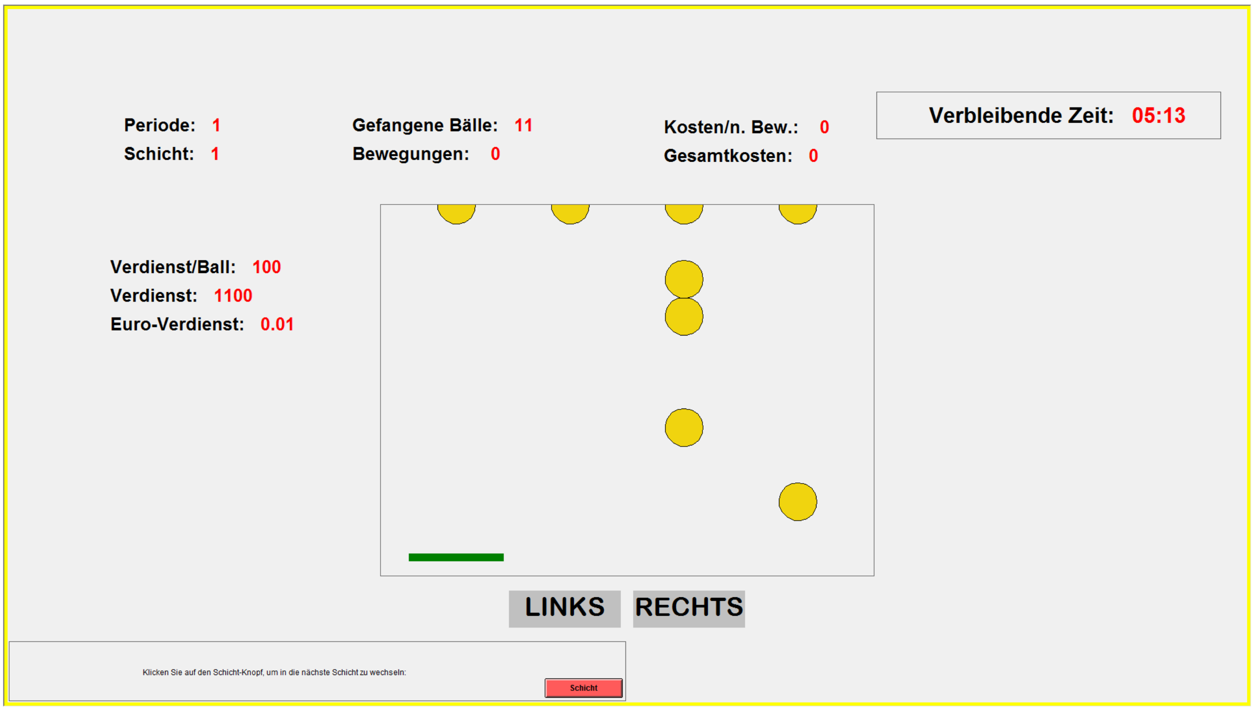


Figure 4: Example screenshot of the ball catching task (with 'shift change' button at the bottom)
Source: Authors' presentation.

Moving the tray is costly in monetary terms; this can be interpreted as the labor effort employed in a shift. e_i designates the number of movements in a shift.[7] To implement an increasing marginal cost of effort, we use the following unit cost function in each shift i: $c(e_i + 1) = 0.1 \times (e_i)^2$ with $e_i + 1$ being the next movement and e_i the number of movements so far.[8] At the beginning of each work-shift, the unit cost function is reset, $e_i(0) = 0$. The total cost per shift is given by the sum of unit costs, $C_i(e_i) = \sum_{k=0}^{e_i} c(k)$. Therefore, this task generates a tradeoff between returns from catching balls, R_i, and the total cost of effort, $C_i(e_i)$. The point earnings in any one of the two shifts is then given by the revenue minus cost, $P_i = R_i - C_i$. The euro earnings are calculated by $\text{Euro}_i = 4 \times [\ln(P_i) - 7]$. The variables number of caught balls, unit cost of the next movement, total cost, number of caught balls, point earnings per ball, and total point and euro earnings in the current work-shift are continuously updated on-screen during the task. Once the task is started by pressing the start button, it cannot be paused. When the work-shift ends, a feedback screen (with the statistics mentioned before) is shown.

Part 1 of the experiment: Trial periods Part 1 of the experiment involves three trial periods. During this phase, we let subjects play three incentivized trial periods so they can familiarize themselves with the user interface and mechanics of the task. Only one of the three trial periods is chosen randomly for payoff and feedback about the chosen period is only shown at the very end of the experiment.[9] In a first trial period, we deviate from the costly effort-incentive structure and make movements costless. We also abstract from the concave consumption function. Subjects are given 180 seconds to catch balls, with each caught ball generating earnings of 1 euro cent. There is no tradeoff between the returns from catching balls and the monetary costs of effort in this trial period. The subjects' performance in this trial period will serve as an individual ability benchmark. In the following two trial periods (and for the rest of the experiment), subjects work with the concave consumption function, the convex cost function, and the point earnings outlined

[7] In contrast to many other real-effort tasks that are designed to be tedious for the subjects in order to "bring the task more in line with what people consider labor" (Charness and Kuhn 2011, p. 243-244), the ball-catching task explicitly quantifies the cost of effort in monetary terms. Hence, we consider the ball-catching task ideal for our research questions. Even if subjects enjoy the task, the cost of effort should keep them from exercising more effort than necessary.

[8] We round the unit costs up to one integer in order not to confuse participants with the decimals.

[9] This is a common technique in order to avoid portfolio effects when subjects make multiple decisions. It also helps us to keep each decision salient by paying a relatively high amount per decision. See Charness et al. (2016) for a discussion of paying one or few decisions vs. paying all.

before. In the second trial period, subjects work on the task and earn the certain wage, $w = 100$ for 180 seconds. In the third trial period, subjects work under uncertainty and either earn the low or the high wage, $w = 20$ or $w = 180$, for 180 seconds.

Part 2 of the experiment: Main treatments In Part 2, we conduct the four main treatments described in Section 2. In the instructions and on-screen we talk about four rounds, not about treatments. Each of the four rounds consists of two periods of 180 seconds each (the first one with the certain wage, the second with the uncertain wage) and two work-shifts (which is defined as the time where subjects work without a break on the task). Only one of the four rounds is chosen randomly for payoff. Furthermore, feedback about the chosen round is only presented at the very end of the experiment.

Round I This is the simplest treatment as subjects have neither the savings nor the time allocation option at their disposal. Subjects work on the task for two work-shifts that coincide with the periods (à 180 seconds). In the first work-shift, subjects earn the certain piece-rate $w_1 = 100$. In the second work-shift, they work under uncertainty and earn either the high rate, $w_2 = 180$, or the low rate, $w_2 = 20$. The instructions stress that the probability for the low or high rate is equal and independently drawn in each of the rounds.

Round II This round differs from Round I only in the savings decision. If subjects earned a positive euro amount in the first work-shift of this round, they enter a screen where they can calculate the consequences of hypothetical saving decisions with a slider. The then enter the amount of points they would like to save in a separate box. (The savings amount has to be positive, $s \geq 0$, and the highest amount that subjects can save is limited so that the euro earnings in work-shift 1 become zero). After that they press the OK button and proceed to the second work-shift. The amount of points saved is then deducted from the point earnings of the first work-shift and added to the point earnings in the second work-shift. See Figure D.1 in the Appendix for a screenshot of the savings screen.

Round III This round differs from Round I in the time allocation between the two work-shifts. Subjects can divide the total amount of time, $T = 360$ seconds, between the two work-shifts. This is implemented in the following way: In work-shift 1 subjects are shown a button that allows them to immediately switch to work-shift 2 at any point of time (see Figure 4 for a screen-shot of a first work-shift with the switch button at the lower left corner of the task screen). The time remaining of the initial 360 seconds is then spent in the second work-shift. As soon as subjects enter the second period, the low wage's point revenue and euro earnings are displayed on the left-hand side of the task box, and the high wage's on the right-hand side of the task box.

Round IV In this round, both the savings decision of Round II and the time allocation of Round III are available to the subjects. First, subjects had to decide when to end work-shift 1. After being shown feedback on their outcomes in work-shift 1, subjects entered the savings screen where they could enter their savings decision.

Part 3 of the experiment: Elicitation of risk aversion and prudence In order to elicit the risk aversion and prudence of the subjects, we consecutively presented them with 12 binary choices between lotteries, as suggested by Noussair et al. (2014). We use five choices regarding risk aversion, five choices regarding prudence and two choices to disentangle risk aversion and prudence.[10]

All instructions for Part 3 were only shown on-screen (the printed instructions did not cover the third part of the experiment, though it was announced). Subjects were presented with one choice at a time. The on-screen presentation of the choices is very similar to the presentation in Noussair et al. (2014). An example screenshot is provided in the Appendix (Figure D.2). Due to the potentially very high payoff of up to 165 euros, each subject only had a 1 in 20 chance of being randomly selected to receive a monetary payment from Part 3 of the experiment (which lasted about five minutes). If a subject's decisions were selected for payoff, one of her 12 decisions was randomly chosen for payoff and the euro earnings were determined randomly according the subjects' decision. Again, all randomizations were computerized and feedback only given after the post-experimental questionnaire.

Post-experimental questionnaire In the post-experimental questionnaire, we asked the subjects for their gender, age, field of study, their number of semesters at university (including undergraduate studies), and how strenuous they perceived the experiment to be (on a scale from 1 (not at all strenuous) to 6 (very strenuous)). We also asked for a subjective self-assessment of their general level of risk aversion (the wording of this question is identical that used by the German Socioeconomic Panel (SOEP), with answers ranging from 0 (not at all willing to take risks) to 10 (very

[10] To be more precise, we used the choices *Riskav1* to *Riskav5*, the choices *Prud1* to *Prud5*, and choices *RaEU1* and *PrudEU2* (in this order) in Table 1 in (Noussair et al. 2014, p.331).

willing to take risks)). We also asked whether subjects knew anybody who previously participated in this experiment and whether they tended to pay attention to the low or to the high piece-rate in the periods where the rate was uncertain.

Procedures and subjects Upon arrival at the laboratory, the subjects were seated in separate booths. Then, the subjects received printed instructions (which included tables with selected values of the cost and consumption functions. After reading the instructions, the subjects had to answer a set of control questions correctly in order to proceed.[11] The experiment was computerized. Only after the subjects completed the three parts of the experiment and answered the questionnaire did they receive feedback about the outcomes of the experiment and their euro earnings. Finally, the payoff took place privately in a room separate from the other subjects.

Table 2: Summary of Subjects' Observable Characteristics

	%	SD		%
Age	23.0	(3.90)	*Field*	
Female	60.9	(48.92)	Psychology	1.56
Semester	5.0	(3.84)	Other	8.85
Extremely risk averse	42.2		Economics	10.42
Very, very risk averse	10.9		Humanities	10.42
Very risk averse	15.6		Sciences	12.5
Risk averse	9.4		Other social science	17.19
Not risk averse	4.7		Law	18.75
Risk loving	2.6		Business	20.31
Other	14.6		*Subjective Effort*	
Variance			Not demanding at all	6.25
Extremely prudent	65.1		Not demanding	28.65
Very prudent	7.3		Not demanding, not effortless	35.42
Prudent	4.7		Somewhat demanding	21.35
Not prudent	4.2		Quite demanding	6.77
Other	18.8		Very demanding	1.56
Stakes			*Attention to Risk*	
Extremely prudent	68.2		Inattentive	7.29
Very prudent	7.8		Risk pessimist	59.38
Prudent	3.6		Risk realist	24.48
Other	15.6		Risk optimist	8.85
Not prudent	4.7			
RRA greater 1	46.9			
RP greater 2	89.6			
RRA greater 1 and RP greater 2	41.1			

Source: Authors' calculations.

[11] You can find a translation of the instructions and the control questions in the Appendix.

All experiments were conducted in PLEx, the Potsdam Laboratory for Economic Experiments at Universität Potsdam, in November and December 2017. All 192 subjects were students of Universität Potsdam and other nearby universities (Freie Universität Berlin, Filmuniversität Potsdam, and University of Applied Sciences Potsdam). See Table 2 for summary statistics of our sample. Subjects were invited using ORSEE (Greiner 2015). The experiments were run on z-Tree (Fischbacher 2007), in 19 sessions of 4 to 14 subjects (depending on enrollment to the experimental sessions and attendance of subjects). The laboratory sessions took about 90 minutes. On average, subjects earned about 15 euros (with a minimum of 0 euros and a maximum of 66.20 euros).

4 Results

4.1 Estimation of production functions and derivation of aggregate predictions

As discussed in Section 2 (p. 10f), we need to estimate a production function as supplied in Equation 7 in order to calculate the point predictions for our variables of interest (savings and time spent in the two work-shifts). Figure 5 provides an overview of the means, distributions, and kernel density distributions of the number of caught balls divided by the number of movements ($\text{balls per movement}_i = \text{caught balls}_i/\text{movements}_i$) in the two shifts for all four treatments, pooled for all subjects. The distributions appear to be very similar and display a fair amount of dispersion. We conduct pairwise Kolmogorov-Smirnov tests between the four treatments for the variable in the two shifts: all pairwise comparisons cannot reject the equality of the distributions at the 5%-level. We take this as evidence that we do not observe much learning in our treatments after the previous three trial periods.

Table 3 displays pairwise correlations between balls per movement in the different treatments and shifts. All correlation coefficients lie between 0.420 and 0.729 and are significantly different from zero at the 1%-level. We take this as evidence for behavioral consistency as the dispersion observed in Figure 5 is driven by the subjects' heterogeneity of ability to perform the real-effort task: subjects who perform well in the real-effort task (and catch many balls with one movement) in one treatment and shift, do so in all the other treatments and shifts as well.

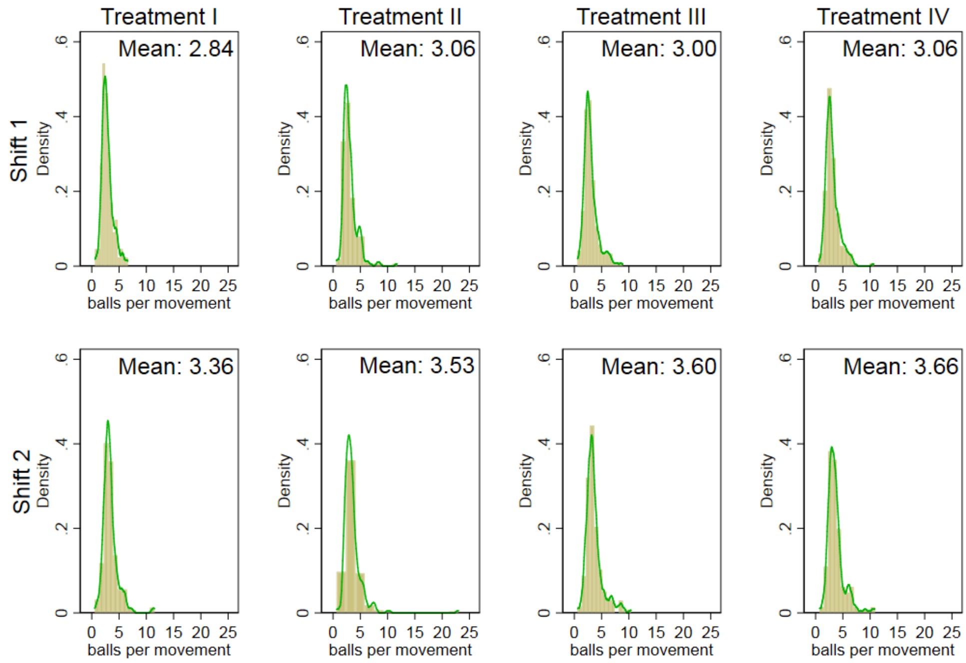


Figure 5: Means, distributions and kernel density distributions of balls per movement in the two shifts of all four treatments

Source: Authors' presentation.

Table 3: Pairwise correlations of balls per movement in the two work-shifts in all treatments

	T1, shift 1	T1, shift 2	T2, shift 1	T2, shift 2	T3, shift 1	T3, shift 2	T4, shift 1
T1, shift 1	1						
T1, shift 2	0.548***	1					
T2, shift 1	0.598***	0.542***	1				
T2, shift 2	0.464***	0.451***	0.525***	1			
T3, shift 1	0.503***	0.420***	0.605***	0.521***	1		
T3, shift 2	0.547***	0.474***	0.586***	0.421***	0.564***	1	
T4, shift 1	0.550***	0.462***	0.615***	0.477***	0.729***	0.512***	1
T4, shift 2	0.553***	0.570***	0.597***	0.429***	0.533***	0.626***	0.620***

Significantly different from zero at $p < 0.01$: ***.
Source: Own calculations.

Given the observed equality between treatments, we pool the four treatments to estimate the production function from the real-effort task data. The following coefficients are estimated from the number of movements and caught balls:

$$\text{balls}(\text{moves}) = 63.337 + 12.491 \times \sqrt{\text{moves}} - 0.001 \times \text{moves}^2$$

Figure 6a displays the estimated production function and the observations in all four treatments (similar to Figure 3 in Gächter et al. 2016, p. 696). Despite the heterogeneity between the subjects' ability, the fit of this simple polynomial regression is quite high with $R^2 = 0.77$. One problem with using this function is that it does not cover the values of movements and balls needed in one single period or shift. Hence, we repeat the exercise separately for the two periods with individual-specific fixed effects:

For period 1 (overall $R^2 = 0.65$):

$$\text{balls}(\text{moves}) = 43.8091 + 6.3099 \times \sqrt{\text{moves}} - 0.0001 \times \text{moves}^2$$

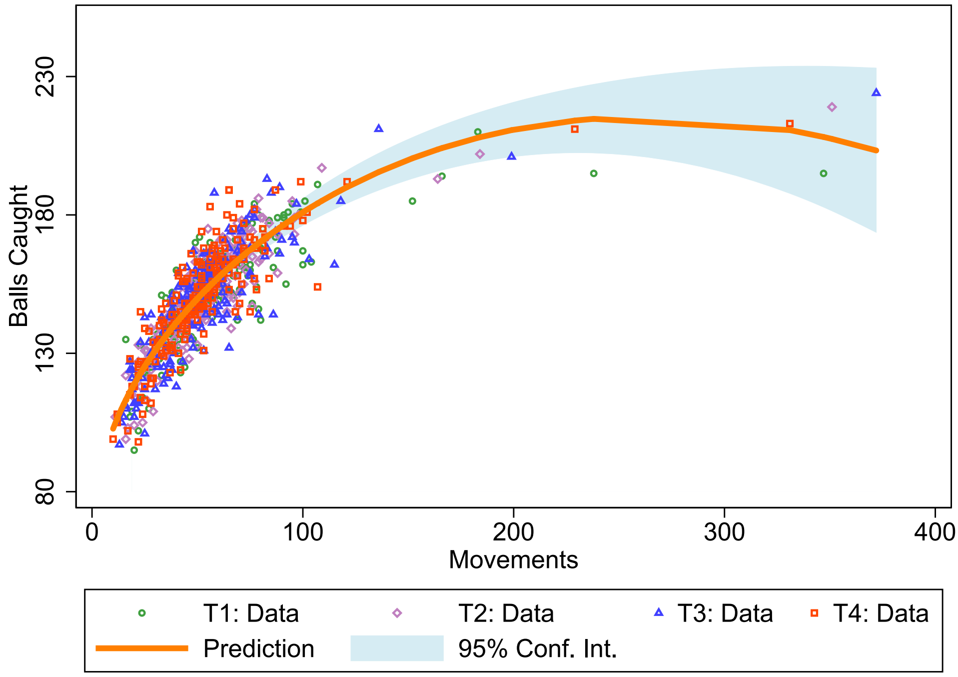
For period 2 (overall $R^2 = 0.73$):

$$\text{balls}(\text{moves}) = 40.8174 + 6.9724 \times \sqrt{\text{moves}} - 0.0010 \times \text{moves}^2$$

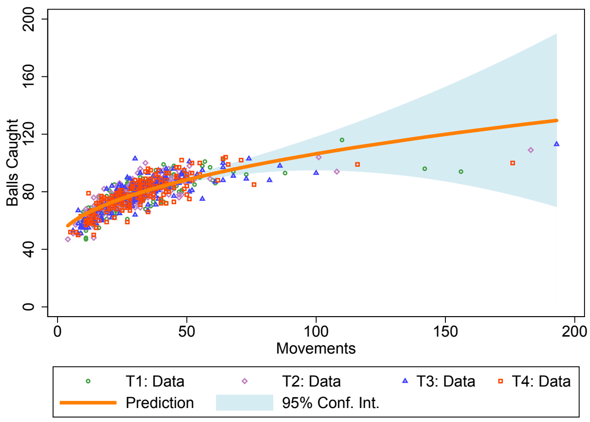
Figure 6b displays these two estimated production functions and the observations in all four treatments.

Table 4 displays the predictions with the two production functions, realized means, and their standard deviations. This table shows first how well the point estimates of the production function fit the average number of balls caught per period and second how well our model predicts movements per period, average savings, and the average shifting choice. The first prediction exercise performs very well; the average number of balls caught is predicted quite precisely for all treatments. No t-test indicates significant deviation of the mean. This is not obvious, because we jointly fit the production function for all treatments as an econometrician would when unable to identify under which restriction choices were made.

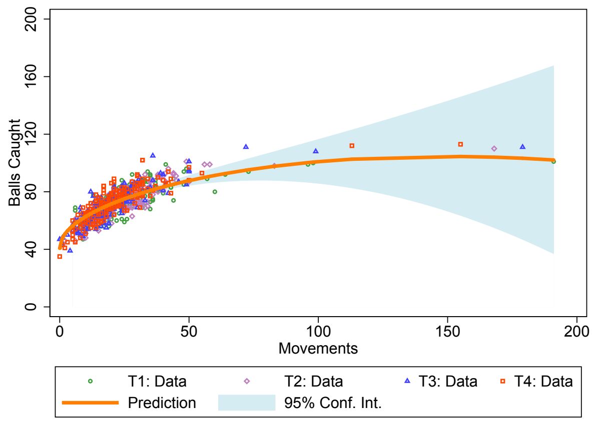
Still, the model prediction exercise is much harder, since deviations from optimal behavior of only a few subjects could lead to a rejection of the model. The model predictions are conditional on the estimates of the production function. Of course, these estimates are measured with error that we do not take into account in the model prediction explicitly. Instead, we report the results from using the point estimates in Table 4. We also use the upper and lower limits of the 95% confidence interval of the production function estimates (not reported here), which leads to fewer predictions being rejected.



(a) Single estimated production function and observations in all four rounds



(b) Period 1



(c) Period 2

Figure 6: Overall and separate estimates of the production functions and observations in all four rounds

Source: Authors' presentation.

Table 4: Predictions and Data

	I	II	III	IV
	Prediction Mean Std. Dev.	Prediction Mean Std. Dev.	Prediction Mean Std. Dev.	Prediction Mean Std. Dev.
Production function predictions				
Balls Caught in Period 1	79	78	79	78
	78	78	79	78
	(10.8)	(10.5)	(11.6)	(11.4)
Balls Caught in Period 2	75	74	71	71
	74	73	71	73
	(10.4)	(11.1)	(12.3)	(12.2)
Model predictions				
Movements in Period 1	25	25	25	25
	33^{***}	31^{***}	33^{***}	32^{***}
	(18.4)	(17.4)	(19.1)	(17.8)
Movements in Period 2	17	20	20	20
	27^{***}	25^{***}	21	22^{*}
	(17.5)	(14.9)	(21.6)	(19.8)
Savings	0	1917	0	Substitutes?
	0	2012	0	1511
	(0.0)	(1244.7)	(0.0)	(1115.6)
Time Spent in Shift 1	180	180	131	Substitutes?
	180	180	166^{***}	171
	(0.0)	(0.0)	(70.5)	(61.0)
Observations	192	192	192	192

Notes: Predicted means from period-specific fractional polynomial individual-specific fixed effects estimations with cluster robust (individual level) standard errors in parentheses (Balls Caught) and model predictions based on point estimates of these estimates. Below predictions are sample means and standard deviations. Significance levels of one-sample t-tests against predicted means are * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.
Source: Authors' calculations.

On average, subjects systematically moved about six to eight moves more than predicted in all treatments. Of course, this is partly due to a few subjects making up to six-times the predicted number of moves. This is similar for period 2 but only in Treatment I and II. In Treatments III and IV, where shifting is allowed, it cannot be rejected that the average number of movements is equal to the prediction.

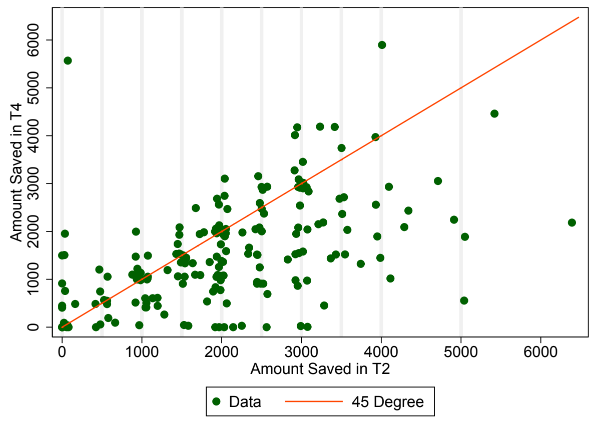
How well does the model predict precautionary savings and shiftings? The table shows that the prediction for Treatment II is not statistically different from the average savings in the data. This shows that the model captures the savings decision extremely well. However, although shifting does occur (time spent in shift 1 is on average 166 seconds), the model predicts even more shifting. Thus, a t-test rejects equality of average time spent in shift 1 and the model prediction. Regarding Treatment IV, there is no single prediction for savings and shiftings. Instead we can predict optimal combinations of these two choices and compare them to actual combinations chosen by the subjects.

4.2 Is Shifting a Substitute for Saving?

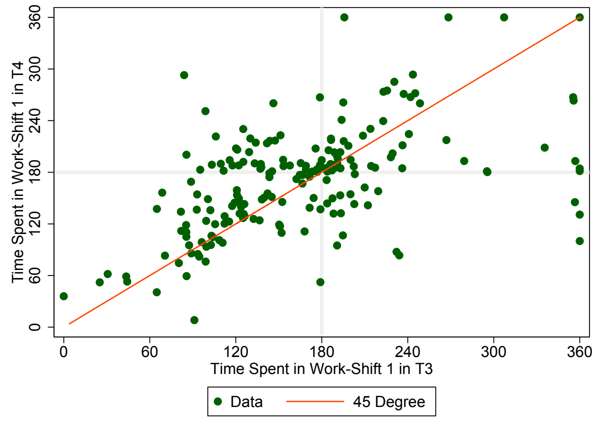
Figure 7 presents visual evidence that subjects substitute the two methods of intertemporal substitution. Figure 7a plots the amount of savings in points in Treatment II, where only saving is allowed, on the horizontal axis and the same figure from Treatment IV, where both saving and shifting are allowed, on the vertical axis. The figure shows that subjects tend to choose savings discretely (0, 500, 1000, 1500, 2000, 2500, 3000, 3500, 4000), though some chose values in between. The solid red line shows all points where savings are identical in both treatments. Strikingly, most saving decisions are below the 45 degree line (though some clusters appear on and above it). This is consistent with substitution of saving and shifting.

Figure 7b shows similar evidence for shifting in Treatments III and IV. Here time spent in work-shift 1 in Treatment III is presented on the horizontal axis and the same figure in Treatment IV is presented on the vertical axis. The bulk of the scatter is above or on the 45 degree line and lies to the left of the 180 seconds vertical line. This shows that most subjects substitute shifting. There seem to be three important cases: either subjects prefer shifting over saving and choose to be on the 45 degree line or they prefer saving over shifting and try to end work-shift 1 at 180 seconds in Treatment IV while performing shifting in Treatment III or they just replicate the 180 seconds restriction in both Treatment III and IV. The latter group seems to be subject to status quo bias, since in Treatment III choosing 180 seconds reduces payoff.

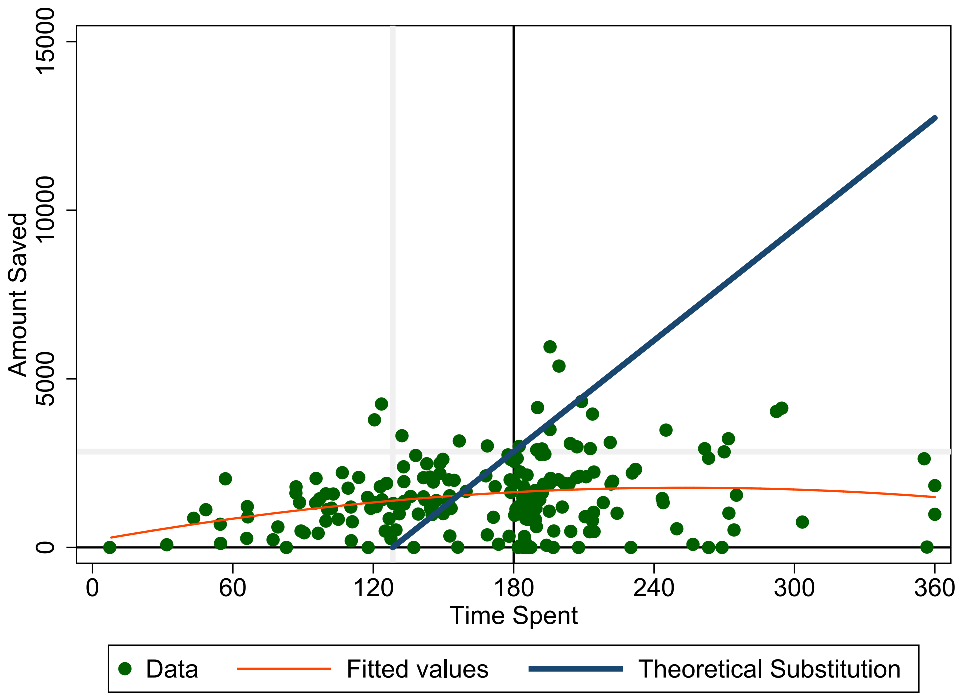
Finally, Figure 7c focuses on Treatment IV, where both saving and shifting are allowed. This figure shows combinations of shifting (horizontal axis) and saving (vertical axis). In principle, subjects should try to choose a point on the solid blue line that yields the highest payoff. Of course, the amount of savings depends on income in the first work-shift. Therefore, most subjects are located below 5,000 points. In fact, many subjects are on the solid blue line, which shows that



(a) H4i: Less Savings if Work-Shift Choice Allowed



(b) H4i: Longer First Work-Shift if Saving Allowed



(c) Shifting IS a Substitute for Savings

Figure 7: Observed substitution of shifting and saving?

Source: Authors' presentation.

they substituted perfectly. However, some subjects are above this line, many of which over-saved given their shifting choice. The bulk of subjects lie below the solid blue line, which means that they under-saved. Again, apparently many subjects tried to replicate the 180 seconds restriction, indicating status quo bias.

Table 5 shows differences between treatments for four key variables from OLS regressions. The first four rows show the results where Treatment I is the base category, and thus the reported coefficients show the difference of the respective dependent variable in Treatments II, III, and IV to its mean in Treatment I (constant). Below, in the lower panel, another set of regressions shows differences from the mean in Treatment IV to Treatments II and III. Strikingly, the difference between Treatment II and I in the first column in the upper part of the table shows that there are significant precautionary savings. In Treatment IV, this figure is significantly different from zero as well; however, it is smaller in magnitude than in Treatment II. The lower panel of the table shows that this difference of about 25% in savings is significantly different from zero. This is expected, since in Treatment IV, shifting and saving are both allowed. Therefore, the smaller magnitude suggests that some savings might have been substituted by shifting. In fact, the second column shows that this is indeed the case. While the constant of 180 seconds shows that shifting was not allowed in Treatment I, the average time spent in the first shift is significantly smaller both in Treatments II (-14 seconds) and IV (-9 seconds). Though, the lower part of this column shows that we cannot reject that the amount of shifting is the same, the point estimate is smaller for Treatment IV, since saving was also allowed. However, this difference only becomes statistically significant if subjects who chose to end work in shift 1 before or at 180 seconds are included in the regression (see third column). In Treatment III, the point estimate of -59 suggests that subjects on average make too much use of shifting, since 179-59=120 seconds is smaller than the predicted 131 seconds. This is clear evidence that a substantial fraction of subjects understand savings and shiftings as substitutes and that they choose to combine these two ways of intertemporal substitution.

The fourth column shows the results of a thought experiment: We know from theory that savings should be zero in the absence of wage risk and that both work shifts should be equally long. Since we observe the number of earned points in each period, which is the relevant income y_1 and y_2 under certainty, we can simply compare this in Treatment II to the actually chosen income minus savings to get a measure of income cuts due to precautionary behavior. Column four shows that income cuts just equal savings from the first column in this case. For the third treatment, shifting is allowed, but no saving. Therefore, we can calculate the income obtained in shift 1. The difference to point income in period 1 is the measure for income cuts in Treatment III. Similarly, in Treatment IV, this difference minus the amount of savings gives total income cuts.

Table 5: Differences of Treatments

	Savings	Time Shift 1	Time Shift 1 ≤180	Income Cut	Income Cut>0	Balls per Move S1	Balls per Move S2
Treatment II-I	2012***			2012***	2061***	0***	0
	(90.0)			(90.0)	(139.5)	(0.1)	(0.1)
Treatment III-I		-14***	-59***	935***	2104***	0*	0**
		(5.1)	(3.2)	(146.9)	(172.8)	(0.1)	(0.1)
Treatment IV-I	1511***	-9**	-55***	2117***	2507***	0***	0***
	(80.7)	(4.4)	(3.5)	(158.8)	(167.0)	(0.1)	(0.1)
Constant (I)	0	180***	179***	0	142	3***	3***
	(49.9)	(2.8)	(1.5)	(75.7)	(119.1)	(0.1)	(0.1)
Observations	576	576	397	768	516	767	755
Treatment II-IV	500***			-106	-431***		
	(82.2)			(153.7)	(136.6)		
Treatment III-IV		-5	-8**	-1183***	-420***		
		(4.7)	(3.5)	(153.8)	(148.2)		
Constant (IV)	1511***	171***	126***	2118***	2668***		
	(41.1)	(2.3)	(1.9)	(87.5)	(78.9)		
Observations	384	384	205	576	451		

Estimation Equation: Difference in difference estimated using individual-specific fixed effects.
Inference: Cluster robust (individual level) standard errors are in parentheses, significance levels are * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.
Source: Authors' calculations.

Using the entire sample, average income cuts in Treatment III seem to be too low to achieve the optimal amount of income cuts, while in Treatment IV the average amount is very close to the optimal. Statistically the former value is different from that of Treatment II but the latter is not. In the next column, we exclude all subjects from the sample that did not save, i.e. who have negative income cuts. This shows that while in Treatments II and III savings and shiftings were virtually perfectly substituted, in Treatment IV significant excess income cuts occur.

Finally, the last two columns show that productivity is economically not significantly different across treatments, although sometimes statistically significant differences are detected. The constant shows that on average, the subjects caught three balls.

Are these different usages of the two channels for precautionary behavior reflected in the euro earnings of the subjects? Figure 8 shows how expected earnings vary across and within treatments conditional on observed choices.[12] All subjects in Treatment I are piled up in one dimension at exactly half of the work-shift axis, since by design each of the work-shifts is restricted to 180 seconds. Depending on effort choices in each work-shift, earnings range from very low (blue circles) to very high (red triangles). Treatment II allows subjects to save, therefore subjects are scattered in two dimensions spanned by the savings-axis and the vertical expected earnings axis. Clearly, those who do not save or save very low amounts cannot expect high earnings (blue circles or green squares); at about 1/3 of the length of the saving axis (at about 2,000 points saved), there is a cluster of red triangles, indicating that expected earnings are high. Treatment III does not allow saving but does allow shifting.

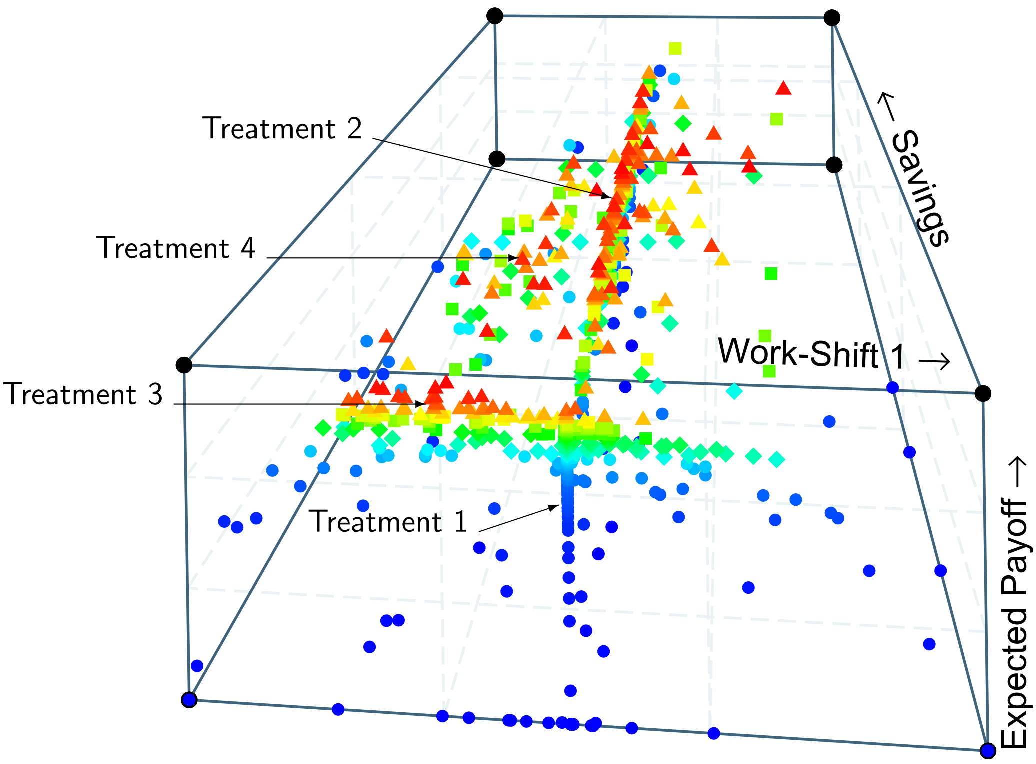


Figure 8: Work-Shift-Savings-Payoff Space

Source: Own presentation using GRAPH3D.

Thus, a two-dimensional space is once again spanned, this time by the work-shift axis and the expected earnings axis. Strikingly, those who chose to end work-shift 1 at about 1/3 of the work-

[12]Figure 8 was generated using the user written Stata ado file *graph3D*, see GRAPH3D.

shift axis (at 120 seconds) expect the highest earnings, as illustrated by the red triangles, while choosing to end shift 1 earlier or later reduces expected earnings substantially. Finally, Treatment IV allows subjects to scatter in a three-dimensional space because both saving and shifting is allowed. The figure shows that subjects on or close to the theoretical line of substitution between shifting and saving expect highest earnings. Notably, it seems as if most subjects try to get close to the optimum.

However, do average expected euro earnings differ depending on which choices are available? To answer this question, we conduct OLS regressions of expected euro earnings (euro earnings for low and high wages, weighted with equal probability), euro earnings if the low wage is realized, and euro earnings if the high wage is realized on treatment dummies. Table 6 shows the results.

Table 6: OLS regression of euro earnings on treatment dummies

	Expected euro earnings	Low Euro earnings	High euro earnings
Treatment I	(baseline)	(baseline)	(baseline)
Treatment II	2.434^{***,b}	5.009^{***,b}	-0.140
	(0.412)	(0.583)	(0.365)
Treatment III	1.088^{**,a,c}	2.789^{***,a,c}	-0.613
	(0.525)	(0.681)	(0.518)
Treatment IV	2.092^{***,b}	4.692^{***,b}	-0.509
	(0.543)	(0.679)	(0.534)
Constant	8.764***	2.385***	15.143***
	(0.710)	(0.838)	(0.674)
R^2	0.014	0.043	0.001
Observations	768	768	768

Robust standard errors clustered at subject level.
Significantly different from zero at the 1%-level: ***, 5%-level: **.
Significantly different from Treatment II's coefficient at the 1%-level: ^{a}, from Treatment III's: ^{b}, from Treatment IV's: ^{c}.
Source: Own calculations.

In the first column, we observe that subjects in Treatments II, III, and IV earn significantly more than in Treatment I (before knowing which of the two possible states of the world occurs). When we compare the earning differences in Treatments II, III, and IV, we see that earnings in Treatments II and IV are not significantly different from one another and that earnings in Treatment III are significantly lower than in Treatments II and IV. As reported earlier, the saving behavior in Treatment II, which is indistinguishable from optimum, leads to higher euro earnings than both the shifting behavior in Treatment III (where we observed too little shifting) and the mix of saving and shifting in Treatment IV (where we observed in total over-saving).

Columns 2 and 3 show how euro earnings are affected ex-post. In case the 'bad' state of the world occurs, in column 2 the same pattern as under uncertainty emerges (only with higher magnitudes of the coefficients). This means that subjects use saving and shifting as a 'rainy day' precautionary measures. In column 3 we can see how much income the subjects give up in the event they do not need to insure against a 'rainy day'. None of the coefficients is significantly different from zero: the price subjects pay for their precautionary behavior is rather low.

4.3 Tests of main hypotheses

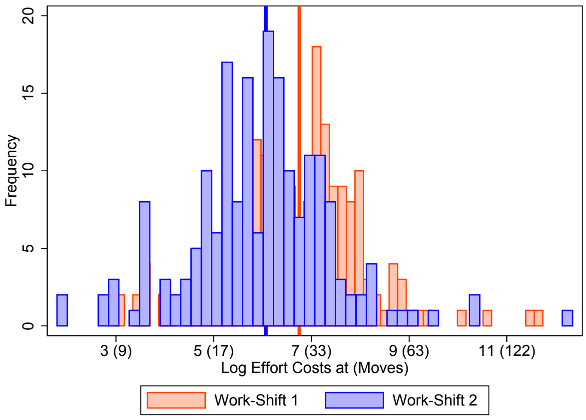
Table 7 reports results on the main hypotheses. First, t-tests suggest that there is the theoretically predicted direct effect of risk, since movements in work-shift 2 of Treatment I are at the 1% level significantly smaller than in work-shift 2. This difference is also reflected in the logarithm of effort costs; again, equality is clearly rejected. This provides strong evidence for hypothesis 1. Figure 9a illustrates this. The distributions of log effort costs and movements are clearly different; the median values of each distribution, as indicated by the blue and red vertical bars, differ substantially.

Result 1: *Effort is smaller in the second work-shift compared to the first work-shift.*

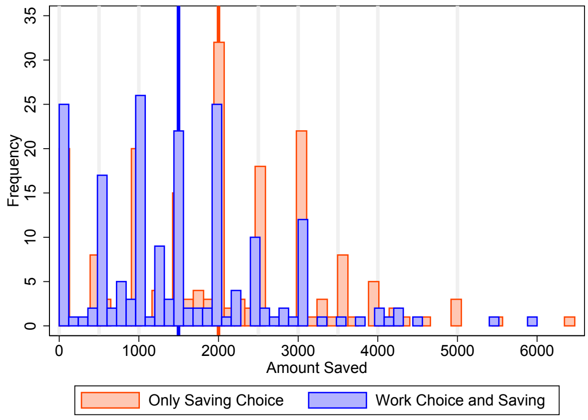
The next set of results shows evidence on precautionary saving. It shows that the hypothesis that precautionary saving is not important must be strongly rejected in a test of proportions. In fact, at least 85.26% (82.22%) of the subjects saved more than 100 points in Treatment II (Treatment IV) according to the 95% confidence interval. This provides strong evidence for hypothesis 2 i. Both bounds of the confidence interval are somewhat smaller in Treatment IV. This suggests that the possibility to end the first work-shift earlier allowed some subjects to substitute shifting entirely for saving, and save less than 100 points in Treatment IV. Figure 9b shows that only 20 (25) subjects out of the 192 chose not to save in Treatment III (IV). Moreover, the medians of the amounts saved (blue and red vertical lines) are strictly positive and of similar magnitude as the means reported in Table 5.

We again conduct t-tests to see whether precautionary effort is present. The results show that movements in both work-shifts are statistically different with a p-value of 1.6%. Although this supports the notion that some subjects might have tried to use precautionary effort, the difference is economically not very important. Similarly, the logarithm of effort costs is statistically different at the 1% significance level. The confidence interval shows that this difference is not in the order of magnitude of the direct effect of wage risk. This provides some evidence for hypothesis 2 ii. Figure 9c provides graphical evidence for this. The medians lie exactly above each other and also the distributions do not differ much.

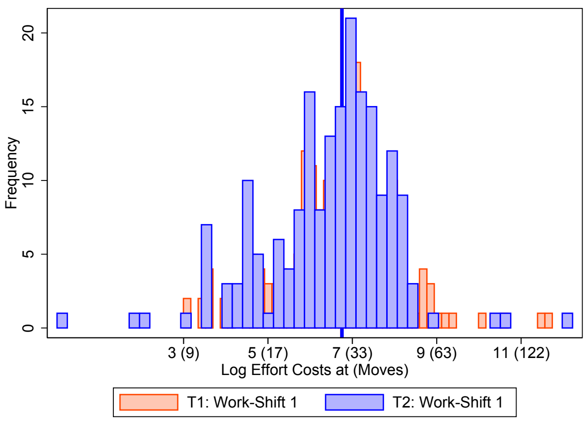
Result 2: *i. In anticipation of risk in the second period, savings are strictly positive. ii. As predicted, precautionary effort is absent.*



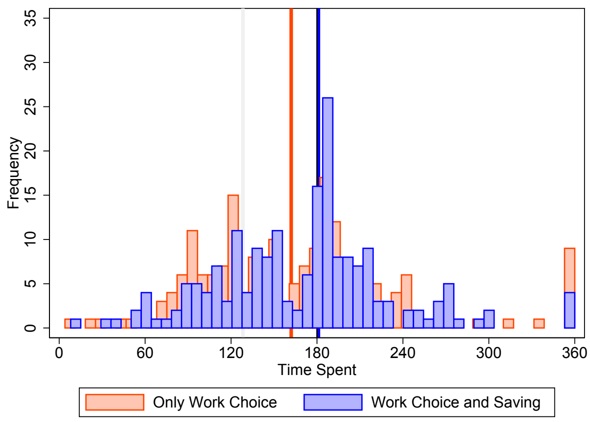
(a) H1: Effort Smaller in Second Work-Shift than in First Work-Shift



(b) H2i: Precautionary Savings are Positive for Most



(c) H2ii: Absence of Precautionary Effort (Higher First Shift Effort)



(d) H3i: Work-shift 1 is Shorter Than Work-Shift 2 for Most

Figure 9: Tests of hypotheses

Source: Authors' presentation.

Table 7: Tests of Hypotheses

H1: Effort Smaller in Second Work-Shift than in First Work-Shift			
	TI Shift 1	TI Shift 2	Difference 95% Conf. Interval
Movements	32.71	26.54	4.61-7.75
Log Effort Cost	6.66	5.99	0.52-0.83
H2i: Proportion With Savings Higher than 100 Points			
	TII	TIV	
Mean (%)	89.58	86.98	
Std. Err. (%)	(2.20)	(2.43)	
95% Conf. Interval	85.26-93.90	82.22-91.74	
H2ii: Absence of Precautionary Effort (Higher First Shift Effort)			
	TI Shift 1	TII Shift 1	Difference 95% Conf. Interval
Movements	32.70	30.73	-3.59 to -0.37
Log Effort Cost	6.66	6.46	-0.35 to -0.05
H3i: Proportion With Work Shift 1 Shorter than 180 Seconds			
	TIII	TIV	
Mean (%)	58.85	47.40	
Std. Err. (%)	(3.55)	(3.60)	
95% Conf. Interval	51.89-65.81	40.33-54.46	

Source: Own calculations.

Next, we test precautionary shifting. A test of proportions strongly rejects the hypothesis that precautionary shifting is not important. At least 51.89% (40.33%) of the subjects ended their first work-shift before 180 seconds in Treatment III (Treatment IV). This provides clear evidence in favor of hypothesis 3 i. Strikingly, a smaller fraction of subjects chose shifting in Treatment III than in Treatment IV. This shows that once the possibility of intertemporal substitution via savings was given, many subjects substituted finishing work-shift 1 early with savings.

Interestingly, a smaller percentage of subjects engaged in shifting than in saving. This suggests that some subjects believe these two choices to be equivalent or that they find it harder to determine the optimal end of the work-shift than to chose the optimal amount of savings. This is illustrated in Figure 9d. The median work-shift choice indicated by the solid red bar is less than 180 seconds in Treatment III, where only shifting is possible. However, the median in Treatment IV is exactly at 180 seconds. Both distributions have two local peaks, one at 180 seconds and one at 120 seconds in both treatments. This suggest subjects choose two distinct strategies.

Result 3: *i. Work-shift 1 is shorter than work-shift 2.*
ii. The average payoff is significantly lower if shifting is allowed than if only saving or both saving and shifting are allowed.

Taken together, our results from this an the previous subsections provide evidence that shifting and saving are indeed substitutes, though not for all subjects. Moreover, more choices do not lead to better decisions. In fact, subjects attained the highest payoffs in Treatment II, where they did not need to make an impulsive decision but instead had time to contemplate several possible choices. These results for hypothesis 4 may be summarized as follows.

Result 4: *i. Either work-shift 1 is shorter than work-shift 2, or there are positive savings, or both. Since choosing savings after a work-shift and allocation of work-shifts are perfect substitutes, there is no systematic difference in the frequency of positive savings and shorter first period work-shifts.*
ii. The average payoff is significantly higher if shifting and saving is allowed compared to the case where only shifting is allowed. It is not significantly different from the case where only saving is allowed.

5 Conclusions

This paper presents a novel behavioral strategy for intertemporal substitution. If the wage rate varies over time, the choice of how much time to work allows one to determine the average wage. This is not possible if work-shifts and periods coincide, as in the standard model. This shifting behavior allows intertemporal substitution in the same way as saving behavior. We conduct laboratory experiments that show that agents do in fact regard these channels as substitutes, albeit not as perfect substitutes, as was theoretically predicted.

In the experiment the only reason for engaging in intertemporal substitution was future wage risk. Accordingly, a second important contribution of the paper is that we shed light on an empirical puzzle contained in the precautionary saving literature. In this literature, saving regressions yield only very imprecise estimates and, as a consequence, there is at best mixed evidence on the importance of precautionary saving. By contrast, some studies suggest that precautionary labor supply might be particularly important for the self-employed. We show (i) that even a single level of wage risk may lead to a very broad distribution of savings if individual effort is disregarded and (ii) that a potentially large part of precautionary behavior occurs through shifting and does not affect savings.

This suggests that surveys used for the analysis of saving and labor supply behavior should gather data on shift-specific in addition to period-specific wages. Moreover, the predictions of the standard model might be misleading, particularly when work-shift allocation can be optimized.

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Appendix

A Translation of the Instructions

INSTRUCTIONS

Welcome to this experiment!

In this experiment, you can earn a considerable amount of money. Your earnings in this experiment depend *only* on the choices *you* make during the experiment. Please read the printed instructions and those shown on-screen carefully.

During the experiment, you are not allowed to use electronic devices other than your PC or to talk to other participants. Please only use the computer programs and functions designated for the experiment. Should you have any questions, please raise your hand. We will then quietly answer your question. If the question is of relevance for all participants, we will loudly repeat and answer it.

Outline

Please read the instructions carefully. Afterward, you will answer a few **quiz questions** to make sure you understand everything. Overall, the experiment will take about 1.5 hours.

The experiment is made up of **three parts**. The payoff you are able to receive in each separate part does not depend on your behavior in the other parts.

Part 1

Part 1 is made up of three test periods, which gives you the opportunity to practice the **assignment** you will work on in the second part (the assignment will be explained further down in Part 2). One of the three test periods is randomly chosen for payoff. Only at the end of the experiment, you will be informed about which period was chosen. Further information will show up on your screen.

Part 2

The second part is made up of **four different rounds**, which consist of **two shifts** each. *The time during which you are working on your assignment without an interruption is referred to as a* ***shift***. Only one of the four rounds is relevant for your payoff. Which of the four round earnings will be paid out will be chosen at random. Only at the very end of the experiment, you will be informed about the round that was chosen for payoff.

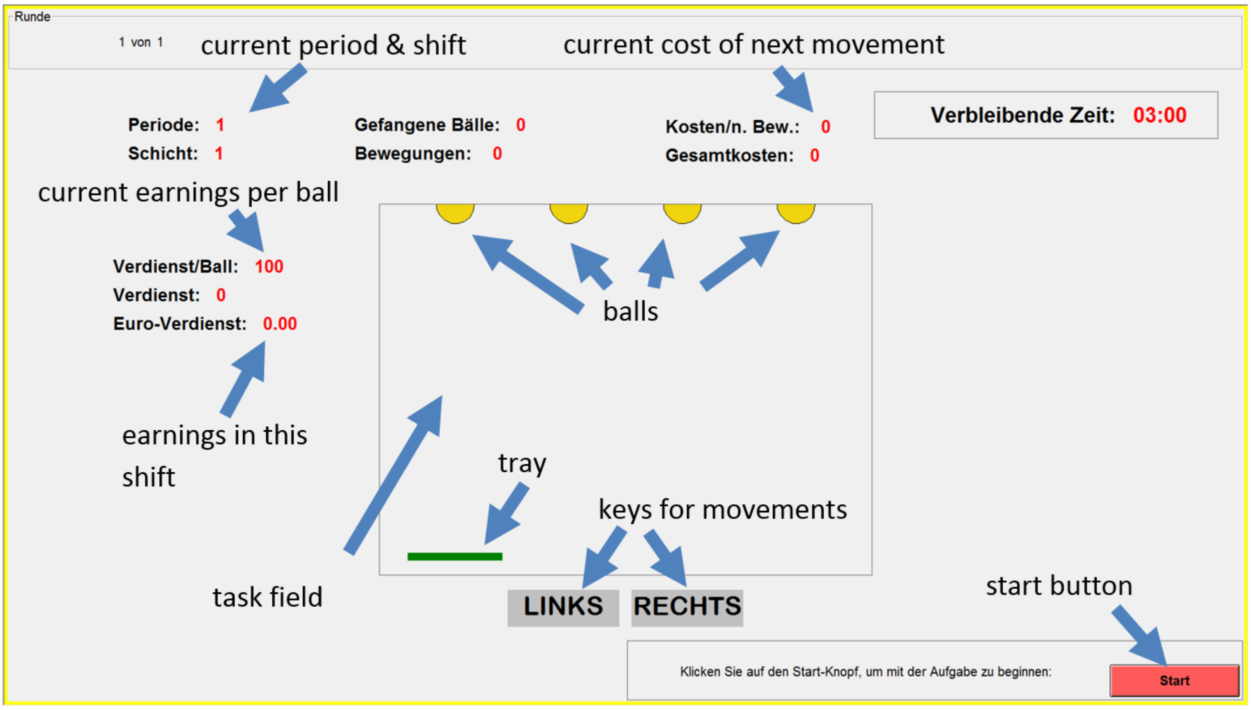
By working on the assignment you can earn **points**. Points are the currency of this experiment. The points you earn during one shift will be converted into euros.

Round 1

In the first round, you are working on the assignment consisting of two shifts. In this round, each shift consists of a period, which always lasts 180 seconds. *A **period** is the time during which a particular earning is paid.*

Your assignment

While working on the assignment you will see a **task field** in the middle of the screen, similar to the following figure.



Left of the task field you can see in which **period** and which **shift** you are currently in. As soon as you click the **start button**, the countdown starts and balls start falling randomly from the upper part of the task field. The remaining time is shown in the upper right corner of the screen. The catching tray can be moved by clicking **"LEFT"** or **"RIGHT"** at the bottom part of the task field, in order to catch the balls. To catch a ball, the **catching tray** has to be positioned right underneath the ball, at the moment the ball touches the tray. As soon as the ball touches the tray, the number of balls caught increases by one. The **number of the balls caught so far** and the **number of the current moves** are shown above the task field.

Each move of the catching tray generates costs. Each ball caught generates earnings. The **cost of the next move** is shown above the task field. Underneath you can find the **current overall costs**. The **current earnings per ball** are shown left of the task field. Underneath you can see your earnings in this shift in points and in euros.

Earnings in points are calculated as followed:

Earnings = Number of balls caught * Earnings per ball caught – Sum of the costs of the moves

Earnings per ball caught

In each period you will be informed about the **earnings per ball caught**. Your earnings per ball caught are always 100 points throughout the first period. In the **second period**, your earnings per ball caught are determined **randomly**. The earnings may either be 180 points or 20 points. Both values occur with equal probability of 50%. In the second period, the point and Euro earnings for both 20 and 180 points can be found on the left and the right side of the task field. Only at the end of the experiment you will learn which earning will be paid in the second period.

It is important to understand that your earnings per ball caught are randomly generated in the second period. Which value your earnings have in one period, **neither** depends on the value your earnings had in previous periods **nor** on the way you behaved in the previous periods. Only at the very end of the experiment you will be informed about the actual value of your earnings in the second period. That implies that for the duration of the task, you do not know which earnings are relevant for payoff, 20 or 180 points.

Costs for moves

At the start of each shift the **cost for a move** is always zero points. The cost per move increases in the number of moves:

Cost per move = 0.1 * (number of moves so far)^2

The cost per move is rounded to the closest integer. A table with chosen function values is included in the instructions.

Example: Supposing the number of your current moves is 30. The costs per move are calculated as 30*30*0.1 = 90. The next click on "LEFT" or "RIGHT" consequently costs 90 points. After the next click, the number of your current moves increases by one. The costs per move are calculated as 31*31*0.1 = 96.1. The result is rounded to the next integer, 96.

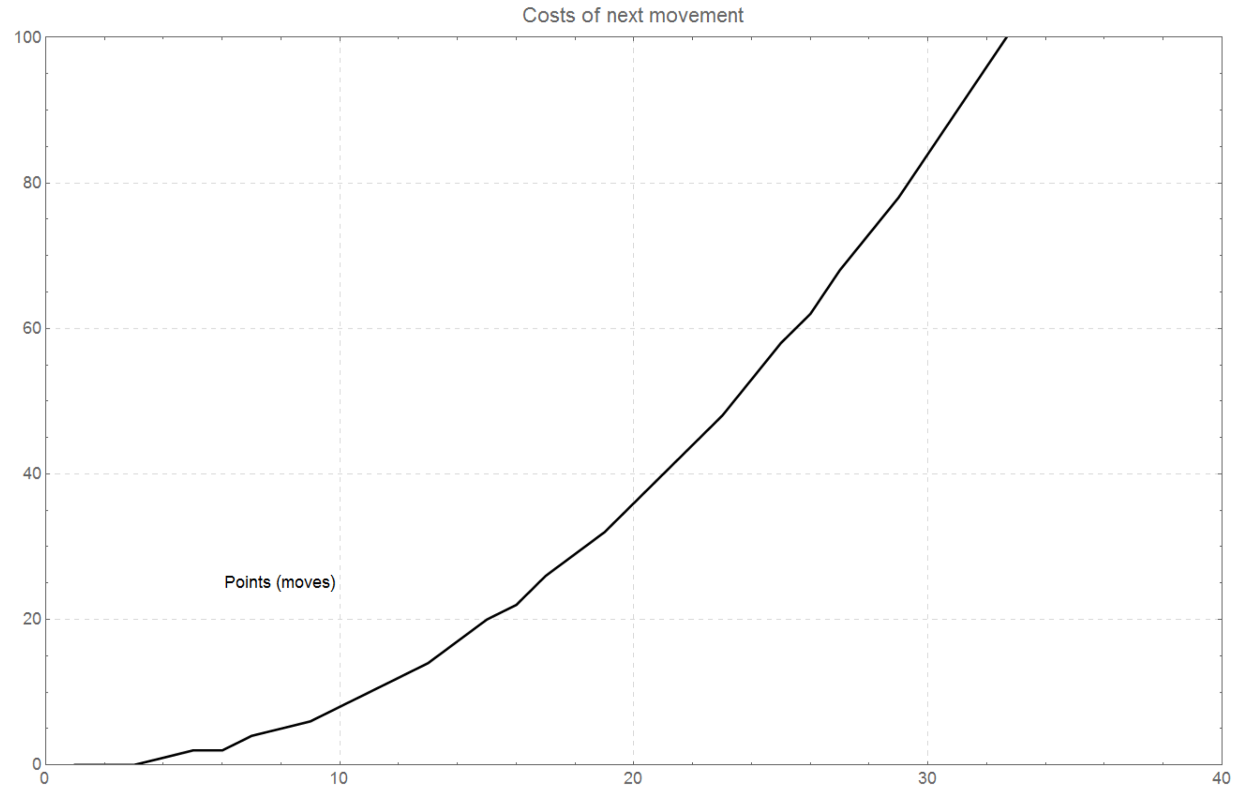
Shift result

The sum of all the points you earned in on shift is your **shift result**. The higher your shift result, meaning the sum of all points earned in one shift, the higher is the payoff in this particular shift. The shift result is converted to euros as followed:

Shift result in euros = 4*[ln(shift result in points) – 7].

The following illustration shows the shift result in euros, depending on the points earned. A table with chosen function values is included in the instructions.

Example: Suppose the number of points you earned in the first shift of a round is 6400. Your result for this shift equals 4*[ln(6400) – 7) = 7.21 euros. In case you earn 100,000 points in the second shift, your result for this shift is 4*[ln(100,000) – 7] = 18.32 euros.



Rounds 2 to 4

The following sections inform you how rounds 2 to 4 differ from round 1.

Round 2

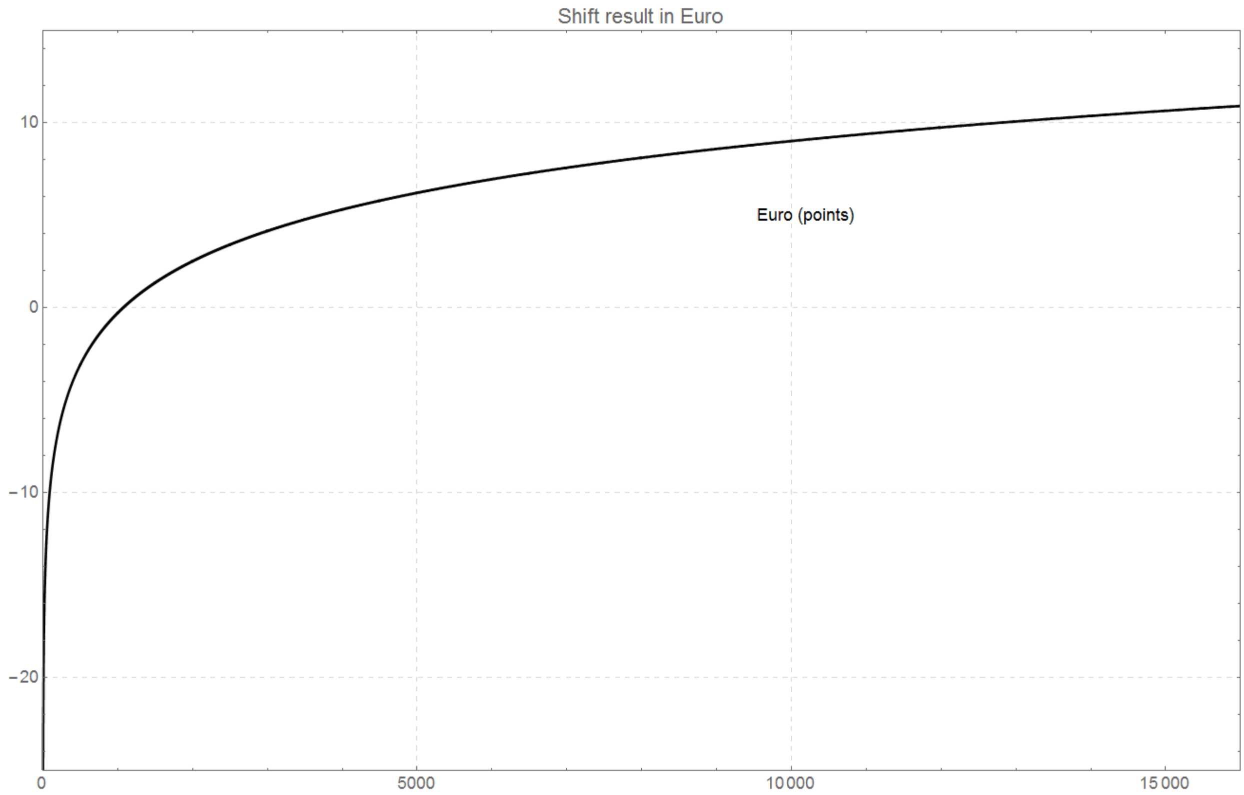
In round 2 you work on the task the same way you did in round 1, for two shifts (which correspond to the periods that last 180 seconds each). Now you have the opportunity to **save** points after the first shift. You can transfer points from the first shift to the second shift. Points that you save are subtracted from the first shift result (accordingly, you earn a lower euro amount in the first shift). The saved points are added to your second shift result (thus, resulting in a higher shift result in euros).

You can save at most so many points that your euro earnings in the first shift are zero. You cannot save a negative amount of points.

Round 3

In round 3 you can decide **how much time** you want to spend in each shift. Overall, you have **360 seconds** at your disposal. The earnings per ball caught in the first period (the first 180 seconds) remain 100 points and the earnings in the second period (the following 180 seconds) remain either 20 or 180 points.

With a button under the task field, you can decide when to end the first shift. After that, the second shift begins.



Example 1: Suppose you end the first shift after 120 seconds. Your shift result for the first shift will be calculated based on the earnings and costs for these 120 seconds. (During these 120 seconds, your earnings per ball caught equal 100 points since you are in the first period.) In the following shift 2, you work on the task for 240 seconds (360 minus 120 seconds). In the first 60 seconds of the second shift, you are still in period 1, meaning you earn 100 points per ball caught. In the following 180 seconds, you are in period 2 and earn either 20 or 180 points per ball caught. Your shift result in points in shift 2 is the sum of the earnings of both periods minus the cost for moves.

Example 2: Suppose you end the first shift after 240 seconds. During the first shift, you are in period 1 during the first 180 seconds and earn 100 points per ball caught. In the following 60 seconds, you are in period 2 and earn either 20 or 180 points (of which the costs are then subtracted). Throughout the second shift (which only lasts 120 seconds) you are in period 2 and earn either 20 or 180 points per ball caught.

Round 4

In round 4 you can save points after the first shift (just as in round 2) as well as decide on the time you want to spend in each shift (just as in round 3).

Part 3

The third part is with regards to content completely unrelated to the first two parts. The instructions for the third part will be shown only on your screen.

Overall pay-out in euros

The result for a round equals the sum of both shift results.

Round result = shift 1 result in euros + shift 2 result in euros.

The overall payoff is calculated as followed:

Overall payoff = result of a random period of part 1 + result of a random round of part 2 + amount earned in part 3

The payoff of the random round is rounded to cents. This amount can drop under zero euros, meaning your payoff might be **negative**. In this case, the loss will be settled with the earnings of the other parts. You will not leave this experiment with a loss: Should the overall payoff be negative, you do not get a pay-out.

Questions

Now please answer the quiz questions about the contents of these instructions. Please raise your arm once you are done. In case you have any questions, please also raise your arm. A person in charge will come to you and answer the question.

B Tables with selected values of the consumption and cost function (part of the printed instructions)

Table B.1: Cost Function

Costs	
Number of movements so far	Cost of next movement in points
0	0
2	0
4	2
6	4
8	6
10	10
12	14
14	20
16	26
18	32
20	40
22	48
24	58
26	68
28	78
30	90
32	102
34	116
36	130
38	144
40	160
42	176
44	194
46	212
48	230
50	250
52	270
54	292
56	314
58	336
60	360

Table B.2: Consumption Function

Shift earnings	
Earned points	Value in euros
0	-25.00
1000	-0.37
2000	2.40
3000	4.03
4000	5.18
5000	6.07
6000	6.80
7000	7.41
8000	7.95
9000	8.42
10000	8.84
11000	9.22
12000	9.57
13000	9.89
14000	10.19
15000	10.46
16000	10.72

C Translation of the quiz questions (with correct answers)

QUIZ QUESTIONS

Please answer the following questions before the experiment starts. With these questions we merely intent to make sure that you understand the instructions properly.

1. True or false? Your earnings in period 1 are always 100 points.
   ☒True ☐False

2. What is the probability that your earnings per ball caught in period 2 are 180 points?
   50%

3. True or false? In rounds 3 and 4 you can influence the total duration for which you earn 100 points per ball caught.
   ☐True ☒False

4. True or false? Each time a new shift begins the costs per movement are reset to zero.
   ☒True ☐False

5. In each shift increase the costs per movement in the number of movements so far. But this increase becomes flatter in the number of movements so far.
   ☐True ☒False

6. Suppose you earned 10,000 points in the first shift and 1,000 points in the second shift. What are your euro earnings in each shift and in the round?
   10,000 points = 8.84 euros; 1,000 points = -0.37 euros; together 8.47 euros

7. Suppose that you (based on the earnings given under 6.) saved 2,000 points. What are your euro earnings in each shift and in the round?
   8,000 points = 7.95 euros; 3,000 points = 4.03 euros; together 11.98 euros

8. Suppose that you spent 100 seconds in the first shift.

   a) How many seconds will you spend in shift 2?
      260 seconds

   b) For how many seconds will you earn 100 points per ball caught in shift 2?
      80 seconds

c) For how many seconds will you earn either 20 or 180 points per ball caught in shift 2?
   180 seconds

9. True or false? You will not learn your payoff during the entire experiment. Only at the very end you will learn this.
   ☒True ☐False

D Example screen-shots of the computer interface

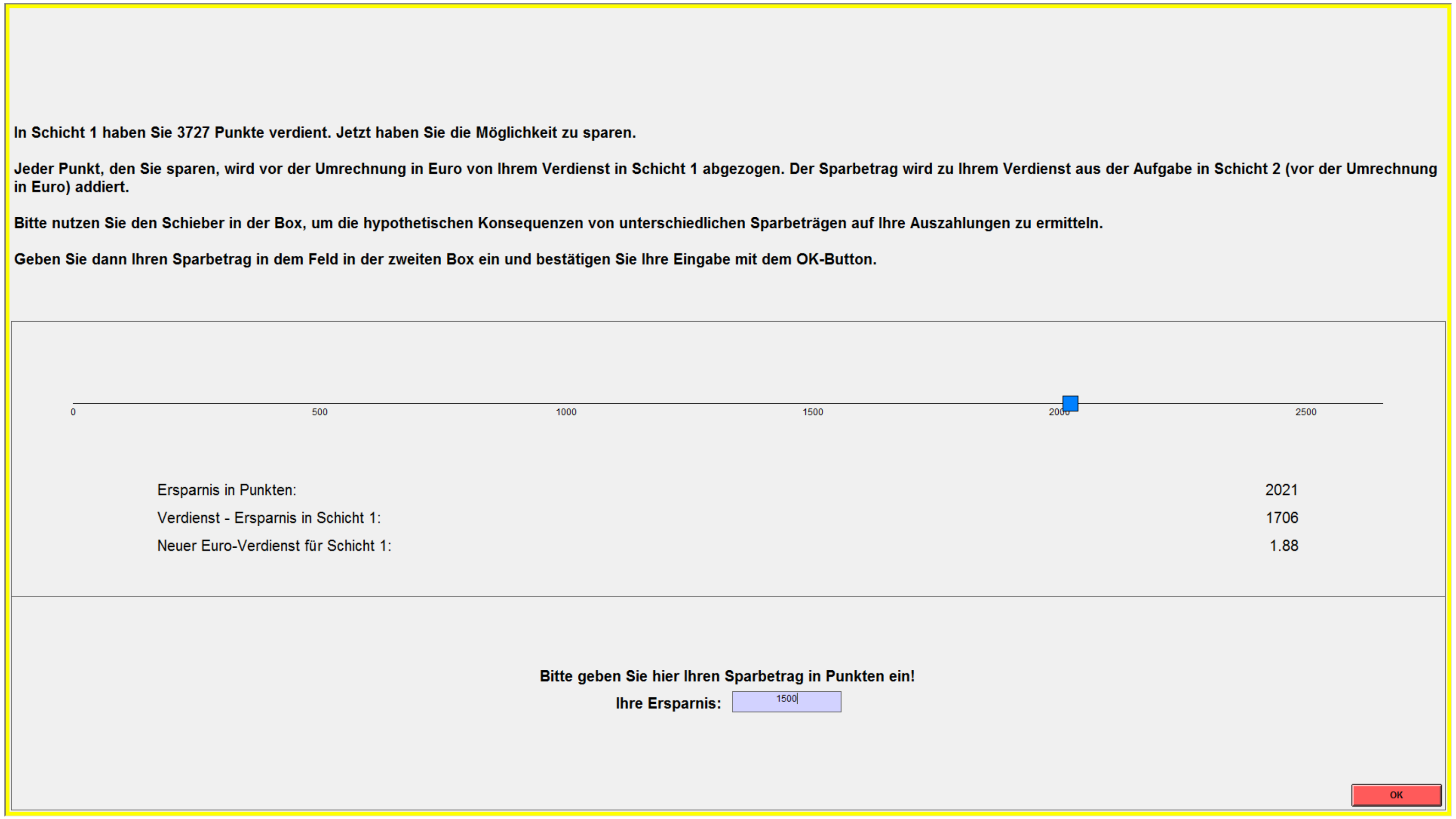


Figure D.1: Screenshot of Saving Screen.

Source: Own interface based on z-Tree.

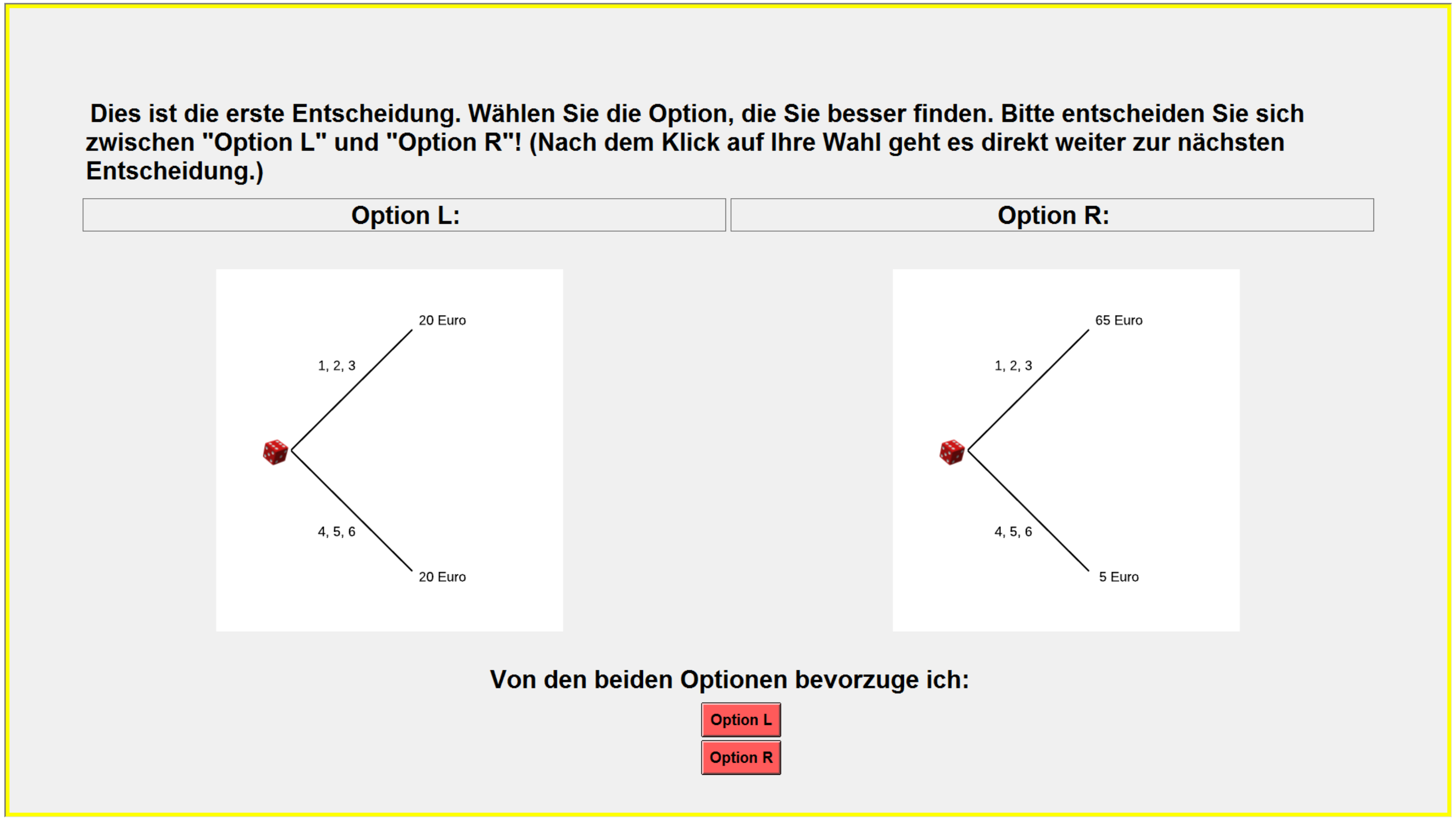


Figure D.2: Screenshot of the Experimental Interface with the Elicitation of the Risk Aversion and Prudence.

Source: Own interface based on z-Tree.

E Existence and Importance of Precautionary Saving in Extant Literature

Table E.3: Literature on Precautionary Saving

Study	Data Set	Data Period	Measures of Risk	Precautionary Saving
Lab experiment				
Meissner and Rostam-Afschar (2017)	Students at TU-Berlin	Eight life cycles à 25 periods	35% of expected value with probability 0.5	No evidence
Bostian and Heinzel (2012)	Students at the University of Virginia	204 life cycles à two periods	two realizations with different probabilities	No evidence
Brown et al. (2009)	Students at National University of Singapore and California Institute of Technology	Seven life cycles à 30 periods	Log-normally distributed	Undersaving
Ballinger et al. (2003)	Students at Univeristy of Huston and Stephen F. Austin State University	One life cycle à 60 periods	Two treatments: 3 francs (5%) or 5 francs (5%); otherwise, 4 francs, 50% 8 francs and 50% 0 francs	$> 0\%$, but undersaving
Hey and Dardanoni (1988)	Students at University of York	between 5 and 15 periods	normally distributed	—
Wealth regression				
Mastrogiacomo and Alessie (2014)	DHS	1993-2008	Subjective earnings variance, second income earner	30%
Fossen and Rostam-Afschar (2013)	SOEP	2002, 2007, 1984–2007	Heteroskedasticity function	0-20%
Hurst et al. (2010)	PSID	1984, 1994, 1981-1987, 1991-1997	Permanent and transitory components of earnings regression	$< 10\%$
Bartzsch (2008)	SOEP	2002, 1980-2003	Variance of income	0-20%
Fuchs-Schündeln and Schündeln (2005)	SOEP	1992-2000	Civil servant indicator	12.9-22.1%
Carroll and Samwick (1998)	PSID	1984, 1981–1987	Variance of income	32-50%
Lusardi (1998)	HRS	?	Self-reported	1-3.5%
Lusardi (1997)	SHIW	1989	Self-reported	2.8%
Kazarosian (1997)	NLS	1966-1981	Permanent and transitory components of earnings regression	29%
Guiso et al. (1992)	SHIW	1989	Self-reported	2%
Dardanoni (1991)	UK Family Expenditure Survey	1984	Variance of labor income	$> 60\%$

Table continued on next page.

Study	Data Set	Data Period	Measures of Risk	Precautionary Saving
Hours of work regression				
Jessen et al. (2017)	SOEP	2001-2012	Standard deviation of past detrended log wages	1.16 hours per week
Benito (2006)	BHPS	1991-2007	Difference between actual and expected financial situation	< 1.4 hours per week
Parker et al. (2005)	PSID	1968-1993	Dtandard deviation of past wages	1.68 hours per week
Pistaferri (2003)	SHIW	1989, 1991, and 1993	Subjective information on future income	negligible
Saving regression				
Broadway and Haisken-DeNew (2017)	HILDA, CASiE	2002, 2006 and 2010	Subjective and objective uncertainty	0.35%
Ventura and Eisenhauer (2006)	SHIW	1993;1995	Average income variance	15-36%
Skinner (1988)	CEX	1972-1973	Occupation indicators	0%
Estimation of Consumption Euler Equation				
Dynan (1993)	CEX	Four quarters of 1985	Consumption variability	0%
Skinner (1988)	CEX			56%
Method of Simulated Moments				
Cagetti (2003)	SCF, PSID	1989, 1992, 1995; 1984, 1989,1994	Permanent and transitory components of earnings regression	50-100%
Gourinchas and Parker (2002)	CEX, PSID	1980-1993	Permanent and transitory components of earnings regression, prob of zero earnings	60-70%
Numerically Simulated Consumption Function				
Pijoan-Mas (2006)	PSID			18.0%
Zeldes (1989)	from other studies			1.6-10%
Skinner (1988)	CEX			56%
Calibrated Closed Form Consumption Function				
Caballero (1991)				> 60%

Notes: Importance figure is sometimes calculated from several sources in the respective paper, please read the paper for details. Datasets are De Nederlandsche Bank household survey (DHS), German Socio-Economic Panel (SOEP), Italian Survey of Household Income and Wealth (SHIW), Household, Income and Labour Dynamics in Australia (HILDA), Consumer Attitudes, Sentiments and Expectations (CASiE), British Household Panel Survey (BHPS), National Longitudinal Survey (NLS), Health and Retirement Study (HRS), Consumer Expenditure Survey (CEX), Survey of Consumer Finances (SCF), Panel Study of Income Dynamics (PSID).