# An empirical model of the decision to switch between electricity contracts

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## Active consumers

Recently, much policy focus on consumers as active participants on the electricity market

- Integration of renewable energy
- Smart grids, demand flexibility
- Price responsiveness is key

## Many margins of choice

On a de-regulated electricity market, housholds face many (complex) margins of choice:

- Appliances/technology/efficiency
- Utilization of appliances
- Choice of retailer
- Choice of transmission capacity
- Choice of electricity contract (focus of this paper!)

Aggregate over all these decisions determine electricity demand, with obvious policy implications: e.g., demand flexibility.

## This paper:

In Sweden, two common contract types:

- price per kWh vary by month ("variable-price contract")
- price per kWh fixed for a year or longer ("fixed-price contracts")

We focus on households on variable-price contracts deciding either to remain on this contract, or switch to a fixed-price contract in response to prices.

- A household choosing a variable-price contract is assumed to believe this to be the most preferable contract.
- However, new information may change this belief.

*How sensitive is the timing of transition away from the variable-price contract to current and past prices?*

## Findings in brief:

- Households respond to history of prices by switching contracts
- Duration on contract vary substantially across alternative price histories
- Not necessarily the case that households interpret higher variable prices as evidence that a fixed-price contract is preferable

## The decision problem

Household have to decide between two states of the world:

- Variable price $\succ$ Fixed price
- Variable price $\prec$ Fixed price

given all the information available at time $t$ (time since start of contract):

- The history $\mathcal{X}_t$ provides households with information about the state of the world (e.g., the sign and magnitude of the expected price differential and temperature)
- $z_0$ is household characteristics (e.g., initial characteristics)

## Belief update

We assume that decision maker learns about the state of the world, $S_t$, in a Bayesian manner.

$$S_t = \begin{cases} 1 & \text{variable price preferable} \\ 0 & \text{fixed price preferable} \end{cases}$$

$$\underbrace{\frac{P[S_t = 1|\mathcal{X}_t, t, z_0, o_0]}{P[S_t = 0|\mathcal{X}_t, t, z_0, o_0]}}_{\text{posterior odds}} = \underbrace{\frac{P[S_t = 1|\mathcal{X}_{t-1}, t-1, z_0, o_0]}{P[S_t = 0|\mathcal{X}_{t-1}, t-1, z_0, o_0]}}_{\text{prior odds}} \cdot \underbrace{\frac{P[x_t|S_t = 1, \mathcal{X}_{t-1}, t]}{P[x_t|S_t = 0, \mathcal{X}_{t-1}, t]}}_{\text{likelihood ratio}}.$$

$$\Rightarrow \ln o_t = \ln o_{t-1} + \ln \lambda_t$$

## Modified Bayesian Updating

- Prior odds at time $t$ are obtained as a simple transformation of the posterior odds obtained after observing all available information at time $t-1$:

$$\underbrace{\frac{P[S_{t+1}=1|\mathcal{X}_t,t,z_0,o_0]}{P[S_{t+1}=0|\mathcal{X}_t,t,z_0,o_0]}}_{\text{prior odds at time } t+1} = \exp(\kappa_0)\left(\underbrace{\frac{P[S_t=1|\mathcal{X}_t,t,z_0,o_0]}{P[S_t=0|\mathcal{X}_t,t,z_0,o_0]}}_{\text{posterior odds at time } t}\right)^{\kappa_1}$$

$$\Rightarrow \ln o_t = \kappa_0 + \kappa_1 \ln o_{t-1} + \ln \lambda_t$$

- This expression describes how, starting from initial odds, the past information accumulates into today's odds depending on the parameters $\kappa_0$ and $\kappa_1$

## Modeling the likelihood ratio $\lambda_t$

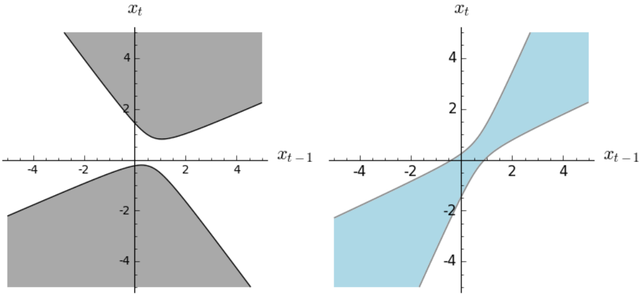
- $\lambda_t$ measures how the information observed at time $t$ contributes to the household's view about the state of the world.
- Simple AR(1) models with homoscedastic normal innovations. Decision maker assumes $x_t$, current information, evolves as:

$$x_t \sim \mathcal{N}(\rho_- x_{t-1} + \mu_-, \sigma^2) \text{ if } S = 1,$$
$$x_t \sim \mathcal{N}(\rho_+ x_{t-1} + \mu_+, \sigma^2) \text{ if } S = 0,$$

- Alternatively, keep AR(1) model, but allow state-specific variance:

$$x_t \sim \mathcal{N}(\rho_- x_{t-1} + \mu_-, \sigma_-^2) \text{ if } S = 1,$$
$$x_t \sim \mathcal{N}(\rho_+ x_{t-1} + \mu_+, \sigma_+^2) \text{ if } S = 0,$$

Figure 1: Sign of Log Likelihood Ratio




Note: The shaded area in each case indicates the region in the plane where the log likelihood ratio is positive. The parameters for the regions on the left hand pane are: $\mu_- = -0.1,\ \mu_+ = 0.1, \rho_- = 0.6, \rho_+ = 0.3, \sigma_- = 0.65$ and $\sigma_+ = 0.55$. To produce the left hand pane, the parameters are kept identical except $\sigma_- = 0.55$ and $\sigma_+ = 0.65$.

## Probability to Keep/Change Contract

The final part of the model concerns the probability to keep the variable-price contract.

- We assume: $P[D_t = 1|\mathcal{X}_t, t, z_0, o_0]$, $t = 1, ... + \infty$, satisfies a logit specification which depends on the initial characteristics of the household, $z_0$, and of the log-odds, $\ln o_t$:

$$P[D_t = 1|\mathcal{X}_t, t, z_0, o_0] = \frac{1}{1 + \exp\{-z_0\pi_0 - \pi_1 \ln o_t\}}$$

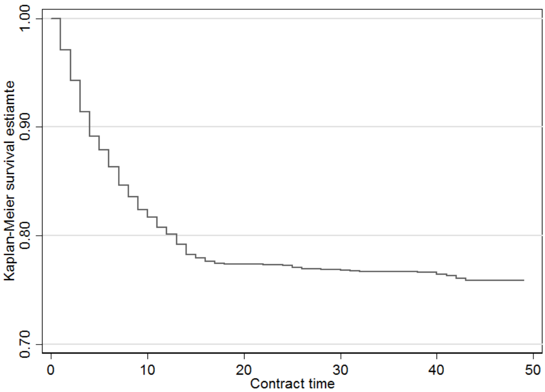
where $\pi_0$ and $\pi_1$ are parameters.
$\ln o_t$ depends on the current information summarized by $\ln \lambda_t$.

- The specification of the probabilities allow for a simple expressions for the individual contributions to the (conditional) likelihood.

## Data

- Data on Skellefteå Krafts customers
- New customers (3353 households) starting variable-price contract June 2010 - February 2012. Sample period ends in June 2014
- 730 households switch to a fixed-price contract
- Contract choice, prices (seasonally adjusted)
- Housing type, heating system at household level
- Income, education, number of inhabitants at zip-code level
- Temperature at postal area level (SMHI, seasonally adjusted)

Figure 2: Kaplan-Meier survival estimate




Note: The figure shows the Kaplan-Meier estimator for the proportion of households remaining on variable-price contracts over time

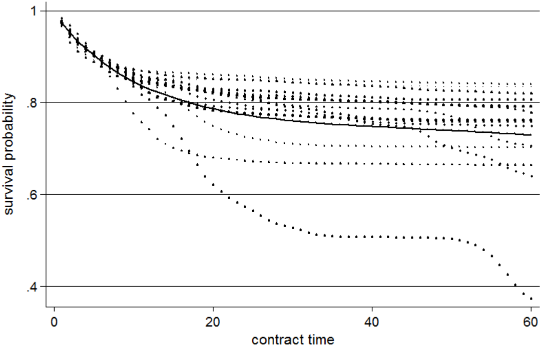
## Estimation results

- Better model fit for heteroskedastic information with trend and discount (LL, AIC, BIC)
- Households downplay past information

Parameter estimates (price responsiveness) somewhat hard to interpret for heteroskedastic model (many interaction terms)

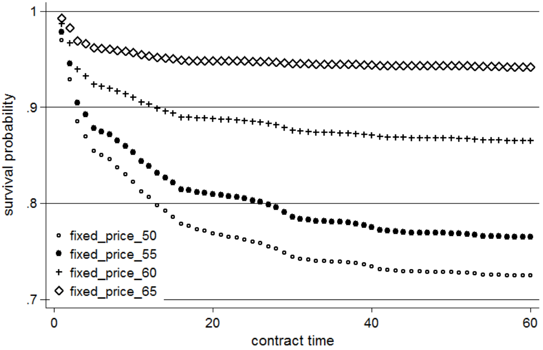
- A straight-forward way of understanding and illustrating results is to produce survival function(s):
- Estimate a time series model for the variable price (AR(1)-ARCH(1)), simulate alternative price differential histories;
- Given that history, calculate the survival probability given the parameter estimates from the survival model;

# Average survival vs. history specific survival, no temperature, homoscedastic information




Note: The figure shows the "average" survival function (survival with a variable-price contract) against the survival function for specific variable price histories.

# The average survival function of a variable-price tariff, temperature info, heteroscedastic information




Note: The figure shows the "average" survival function (survival with a variable-price contract) against different fixed prices. Average weather.

## Conclusions

- Response to prices not obvious; depends on specification of the likelihood ratio
- Households respond to flow of information
- The response is seemingly small in the population, but may be bigger for alternative histories of prices
- Alternative price processes likely in the future, as share of intermittent generation increase
- If more households switch to fixed-price contracts, less price response in the short run