University of Tartu, Estonian Center of Industrial Mathematics, The European Consortium for Mathematics in Industry, COST Action TD1409 Mathematics for industry network

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Estonian Study Group with Industry – ESGI 151

Problem number 4 – LHV Bank fully automated personal finance tool

4a. Drivers of financial balance

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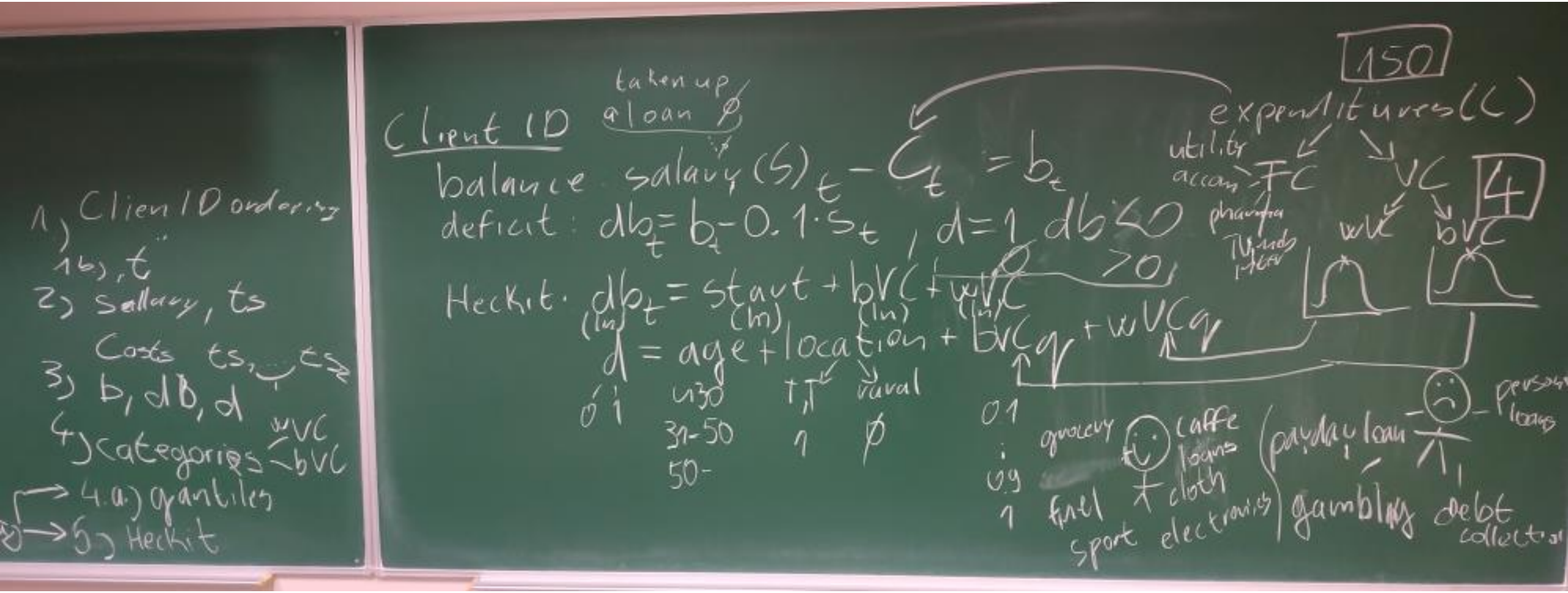
Original concept



Data and Model

Software:
SQL, Matlab, Gretl

Dataset (2018):

- CLIENT_ID (N=500);
- GENDER (F/M);
- AGE (u30, 31-50, a50);
- ADDRESS (T-T, rural);
- STARTING_BALANCE (€);
- CATEGORY (N=150);
- SUM (€)

Model

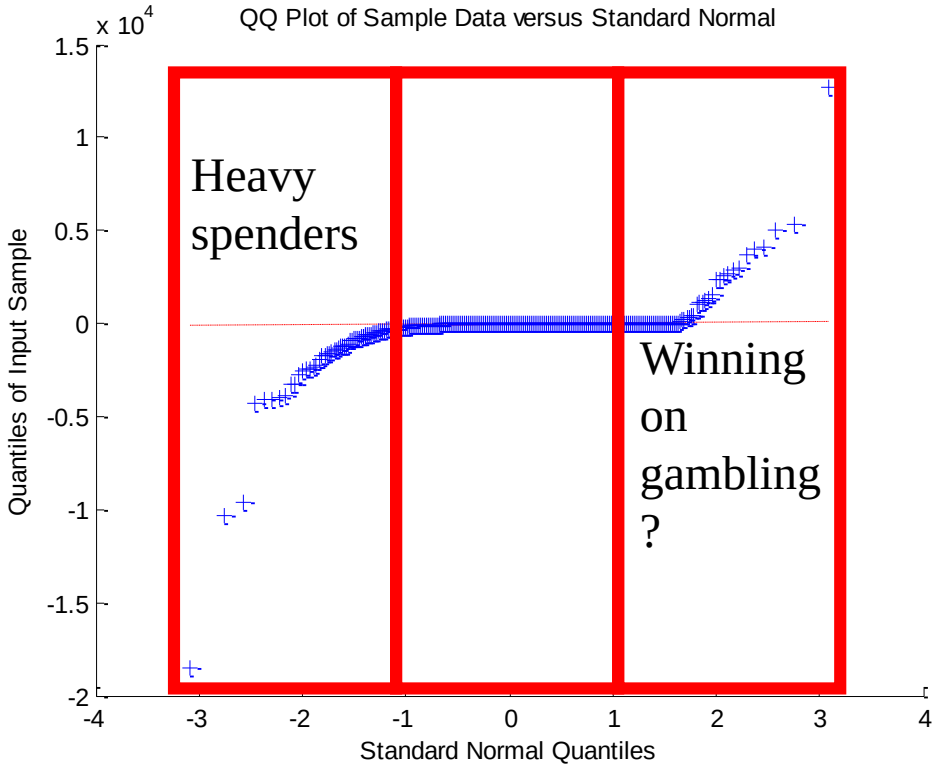
- Balance=Salary – Costs (€, dummy)
- Costs=FC+VC
- VC=whitelisted VC + blacklisted VC
- whitelisted VC (€, 33-66-99%)
  - Groceries, Theatre, Cafes, Fuel, Sport, Books, Household products, Clothing
- Blacklisted VC (€, 33-66-99%)
  - Gambling, Debt collection, Payday loan, Personal loan

Steps

1. Random sampling (N=500) from clients (Client ID) – SQL server
2. String-to-value conversion – Matlab (*165.5 seconds*)
    1. Gender (0-1), Address (0-1), Age (1-2-3), w_cat (0-1), b_cat (0-1),
    2. salary day, sums of salary, w VC, b VC and total costs
    3. New ID and time codes for clients and their transactions (panel regression req.)
    4. Determining 33% spending quantiles for w/b VC
    5. Determining balance and state of deficit
    6. Panel construction
        1. Ln of € spending
        2. Variables: ln_start,ln_w_sum,ln_b_sum,ln_salary_sum,ln_balance,ln_db, deficit_d,w_cat_d,b_cat_d,w_VCq,b_VCq,age,address,gender,ID,Time
3. Heckit model fitting – Gretl

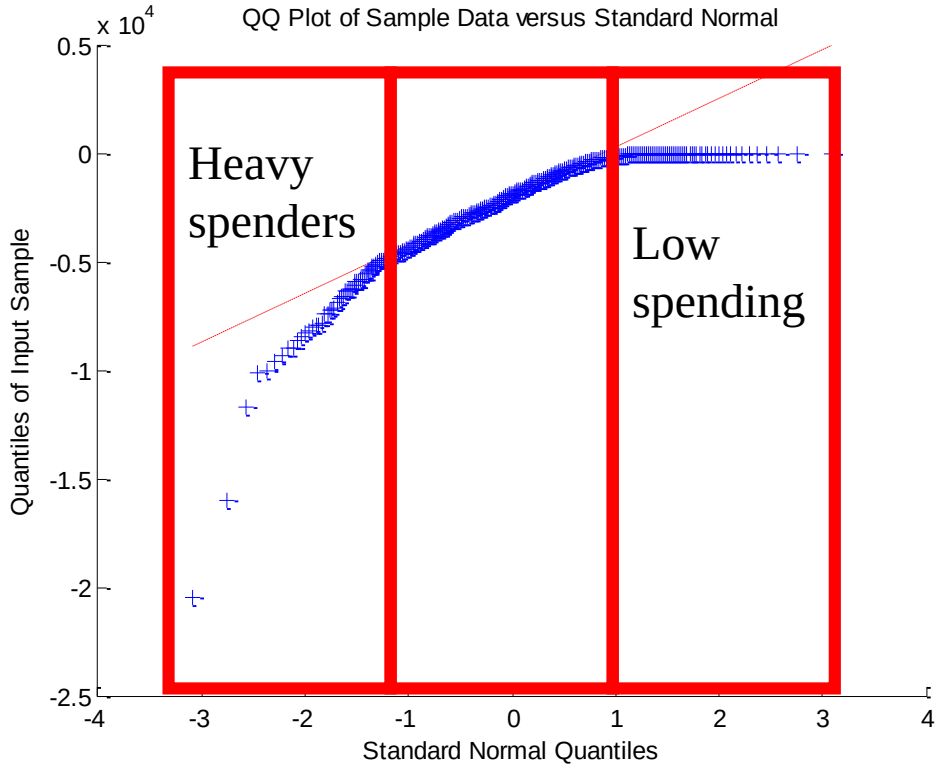
33-33-33% quantiles

QQ plot of blacklisted VC



-1 0 1

QQ plot of whitelisted VC



-1 0 1

Model

- Heckit panel (two-step) regression:
  - The first step is the selection mechanism that sorts and explains the state of balance (Z* = 1 cases)

Selection mechanism (step 1):

$$Z_i^* = w_i'\gamma + u_i;\ Z_i = 1 \text{ if } Z^* > 0, \text{ otherwise 0; where } Z_i = 1 \text{ denotes extreme returns,} \quad (7)$$

$$\text{Prob}(Z_i = 1 | w_i) = \phi(w_i'\gamma) \text{ and } \text{Prob}(Z_i = 0 | w_i) = 1 - \phi(w_i'\gamma). \quad (8)$$

  - The second step is a regression model which explains the drivers of the budgetary balance

Regression model (2nd step):

$$Y_i = X_i'\beta + \varepsilon_i \quad Z_i = 1 \text{ , where } Y_i \text{ is the dynamic conditional correlation.} \quad (9)$$

  - The error terms: uncorrelated, no specification error, lambda significant
- Applied Heckit model:
  - Regression: ln_balance = const. + βln_start + βln_bVC + βln_wVC +ε *labda*
  - Selection eq.: balance_dummy=const. + βage + βaddress + βgender + βwVCq + βbVCq+u
    - Assumptions: $\beta<0$, $\beta>0$, $\beta\sim0$

Greene, W.H. (2003): *Econometric Analysis*. Prentice Hall. Pearson. New Jersey (p. 784, (20-22))
Wooldridge, J.M. (2012): *Introductory Econometrics: A Modern Approach*. Cengage Learning, Mason.

Im, Pesaran and Shin (2003) test of unit root

	first 500	second 500	third 500	forth 500
tbar:	-88.7787	-87.6416	-88.0869	-88.0621
Wbar:	-378.7174	-373.7820	-375.7149	-374.9341
Wbar_pvalue:	**0**	**0**	**0**	**0**
Zbar:	-388.5131	-383.4496	-385.4327	-385.3220
Zbar_pvalue:	**0**	**0**	**0**	**0**
critical:	[-2.3263-1.6449-1.2816]	[-2.3263-1.6449-1.2816]	[-2.3263-1.6449-1.2816]	[-2.3263-1.6449-1.2816]
tbar_DF:	-162.2975	-161.3663	-160.0640	-161.1429
Zbar_DF:	-715.8993	-711.7524	-705.9531	-710.7577
Zbar_DF_pvalue:	**0**	**0**	**0**	**0**
pi:	[14x1double]	[14x1double]	[14x1double]	[14x1double]
tstats_ind:	[14x1double]	[14x1double]	[14x1double]	[14x1double]
pmax:	2	2	2	2
Ti:	[14x1double]	[14x1double]	[14x1double]	[14x1double]
model:	'model with intercept'	'model with intercept'	'model with intercept'	'model with intercept'

No unit root

Im, Pesaran and Shin (2003): Testing for Unit Root in Heterogeneous Panels. *Journal of Econometrics*, 115, 53-74

Results

Two-step Heckit								
	first 500		second 500		third 500		forth 500	
	coeff.	p-value	coeff.	p-value	coeff.	p-value	coeff.	p-value
Dependent variable: ln_db								
const	-0,9349	0,0000***	0,0039	1,92e-040***	-0,9259	0,0000***	-0,9100	0,0000***
ln_start	-0,0254	7,29e-079***	-0,0070	9,27e-016***	-0,0623	1,72e-071***	-0,0701	0,0000***
ln_b_sum	-0,0155	0,1023	-0,0106	0,0002***	-0,0161	0,5287	-0,0561	1,92e-07***
ln_w_sum	0,0857	1,88e-127***	-0,0131	1,45e-078***	0,0748	5,84e-017***	0,0745	1,05e-069***
lambda	**0,2170**	**0,0000*** **	**0,0352**	**1,75e-060*** **	**0,5339**	**2,14e-077*** **	**0,2554**	**4,76e-138*** **
Selection equation (deficit_d)								
const	1,4499	0,0000***	1,5410	0,0000***	2,1928	0,0000***	2,1806	0,0000***
age	-0,0887	8,56e-042***	-0,0073	0,2406	-0,2075	7,34e-157***	-0,1871	1,80e-156***
address	0,2270	2,10e-144***	-0,0548	2,53e-011***	0,0190	0,0630*	-0,1295	3,72e-042***
gender	0,0437	7,00e-07***	-0,0572	5,55e-013***	-0,1465	1,53e-047***	-0,2259	7,83e-132***
w_VCq	-0,5015	0,0000***	-0,1265	9,55e-125***	-0,2657	0,0000***	-0,3009	0,0000***
b_VCq	-0,2921	0,0000***	-0,1870	2,33e-168***	-0,0949	7,90e-029***	0,0195	0,0148**
Total observations:	257564		264327		250769		256649	
Censored observations:	13503 (5,2%)		16009 (6,1%)		8271 (3,3%)		11146 (4,3%)	

Interpretation

Initial surplus →deficit
Blacklisted VC → deficit
Whitelisted VC → sufficit
Lambda: significant

Older ages →sufficit
Metropolitan area → ?
Males → sufficit (?)
Heavy VC spending → d
(whitelisted > blacklisted)

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Discussion

- Theoretical model: simple but works
- Theoretical model can be sophisticated
  - More VC categories
  - Deeper regional breakdown
  - Cash-preference included
- Quantile panel regression
- Additional sample tests (increasing sample size – RAM)