Adoption Costs of Financial Innovation: Evidence from Italian ATM Cards *

Kim P. Huynh† Philipp Schmidt-Dengler‡ Gregor W. Smith§ Angelika Welte¶

December 21, 2016

Technical Appendix: Not meant for publication

Latest version available at:
http://pages.iu.edu/~kphuynh/rsch/hsdsw.html

Abstract

This technical appendix provides in Section 1 a summary of the estimation methods used in the paper while section 2 discusses the asymptotic and bootstrap resampling methods to compute standard errors. Section 3 provides some robustness on the adoption cost results using the logit link function. Finally, section 4 conclude with a summary of the variables used in our analysis.

*Smith acknowledges the Social Sciences and Humanities Research Council of Canada and the Bank of Canada research fellowship programme for support of this research. Schmidt-Dengler acknowledges financial support from the German Science Foundation through Sonderforschungsbereich Transregio 15. Dörte Heger provided excellent research assistance. For constructive comments, we thank Jason Allen, Thomas Lemieux, Héctor Pérez Saiz, Ben Tomlin, and seminar and conference participants. The views in this paper represent those of the authors alone and are not those of the Bank of Canada.

†Currency Department, Bank of Canada. Email: kim@huynh.tv.

‡Department of Economics, University of Vienna. E-mail: philipp.schmidt-dengler@univie.ac.at.

§Department of Economics, Queen's University. Email: smithgw@econ.queensu.ca.

¶Currency Department, Bank of Canada. Email: awelte@bankofcanada.ca.

1. Estimation Methods

This section describes the various estimation methods and decisions used in the paper.

1.1. Computing Transitions

We estimate the transition processes for wealth, consumption and ATM card ownership.

1.1.1. Panel settings

Households in the panel are uniquely identified by the household identifier "nquest" while "anno" corresponds to the year of data collection. Data collection usually takes place every two years, but there is a three year gap between surveys between 1995 and 1998.

Table 1: Waves

Wave	Year
1	1987
2	1989
3	1991
4	1993
5	1995
6	-
7	1998
8	2000
9	2002
10	2004

Since the variable indicating ATM card adoption is not available before 1989, only waves 2 to 5 and waves 7 to 10 are used in the estimation.

1.1.2. Price level and the inflation rate

Consumption and wealth are in deflated to 2004 Euros. The lire to the euro conversion factor used was 1,936.27. We use the GDP Deflator series (13699BIRZF...) from the following database: https://goo.gl/5i7qZS.

1.1.3. Real interest rate

The real interest rate is approximated by $r \cong \ln\left(\frac{1+i}{1+\pi}\right)$ where i is the nominal interest rate and π is the inflation rate. This approximation is used first as $\ln(1+r) \cong \ln\left(\frac{1+i}{1+\pi}\right)$ and then combined with the fact that, for small values of r, $\ln(1+r) \cong r$ (by Taylor-Maclaurin first order approximation).

1.1.4. Variable transformation

The utility of household i at time t depends on $\ln(c_{it})$ where c_{it} is the household's consumption. In particular the household's utility is not defined for non-positive values of c. Therefore, to avoid computational difficulties, we estimate transitions for the log of consumption wealth.

1.1.5. Outliers

Observations with negative wealth or wealth exceeding 12 million Euros were excluded. These observations constitute less then 1 percent of all observations.

1.1.6. Regressions

The reduced form transitions $c_{it} \rightarrow c_{it+1}$ and $w_{it} \rightarrow w_{it+1}$ are estimated by robust linear regression. To obtain representative results, observations are clustered on the household level and weighted "pesofit" or the unit sampling weight provided by the Banca d'Italia.

1.1.7. Retirement, employment and education

When the age of the household head reaches 65, their employment status changes to "retired". Households whose household head is younger than 25 are also excluded since their education and employment status as well as the number of people living in their household are likely subject to changes in the near future. Income transitions are not modeled. That retirement occurs at 65 is supported by the data relating employment status to age.

1.2. Simulation

The number of simulations is 1,000 (S) and the number of time periods is 50 (T), corresponding to 100 years. The set-up begins by drawing for each simulation, time period and individual four shocks, namely for the wealth process under adoption and non adoption and the consumption process under adoption and non-adoption, resulting in $S \times T \times N \times 4$ iid draws from a standard normal distribution. Next, for each simulation, each time period and each region (R) we draw a shock for the nominal interest process, resulting in $S \times T \times R$ iid draws from a standard normal distribution. Finally, for each simulation and each time period, a shock is drawn for the inflation process, resulting in $S \times T$ draws from a standard normal distribution. Wealth and consumptions are simulated on the individual level. Interest and inflation paths are simulated at the regional and national level, respectively. The interest and inflation rates for household i

at time t are the interest rate of the region that i resides in and the the national inflation rate at time t.

The simulated paths of the nominal interest rate and the inflation rate are used to calculate the real interest rate. To ensure that the real interest rate is well-defined we estimate transitions for $\ln(i)$ and $\ln(\pi)$ so that along every simulated path $i > 0$ and $\pi > 0$ implying that $\ln\left(\frac{1+i}{1+\pi}\right)$ exists.

2. Inference

This section discusses how we compute the standard errors via asymptotic and bootstrap resampling methods.

2.1. Asymptotic Standard Errors

The estimates for κ and σ minimize the following least squares criterion $\sum_{i,t} \| \frac{v_{it}^{0,S} - vit^{1,s}}{\sigma} - f_I z_{it} \|^2$. Define $h_{it}(\kappa, \sigma) = \frac{v_{it}^{0,S} - vit^{1,s}}{\sigma}$. The asymptotic covariance matrix of $\mathbf{b} = (\hat{\kappa}, \hat{\sigma})$ is given by

$Est.Asy.Var(\mathbf{b}) = s^2(\mathbf{X^{0\prime}}\mathbf{X}^0)^{-1}$ where $s^2 = \frac{1}{N} \sum_{i,t} \|h_{it}(\mathbf{b}) - f_I(z_{it})\|^2$ and $\mathbf{X}^0 = (\partial h_{it}(\mathbf{b})/\partial \mathbf{b})_{i,t}$ Those derivatives can be requested as output from the MATLAB solver or calculated numerically. We use the output of the solver. Alternatively, some solvers output a Hessian matrix $\mathbf{H}^0$ which can be used in place of $\mathbf{X^{0\prime}}\mathbf{X}^0$. In either case, singularity problems may arise. If a simulated annealing or the simplex method is used to solve the minimization problem, derivatives will have to calculated in separate step after the solver has converged.

2.2. Bootstrap Standard Errors

Bootstrap estimates, standard errors and confidence intervals are obtained for κ and σ using $10,000(B)$ bootstrap replications. For each replication, we draw a sample of size N with replacement from the population. A seed is set to allow for replication of the bootstrap procedure. The minimization problem is then solved on this sample which gives B bootstrap estimates $\hat{\kappa}_b$ and $\hat{\sigma}_b$.

The bootstrap estimates for κ and σ are given by $\hat{\kappa}^B = \frac{1}{B}\sum_b \hat{\kappa}_b$ and $\hat{\sigma}^B = \frac{1}{B}\sum_b \hat{\sigma}_b$. and the bootstrap variance is the variance of the B estimates, namely $V(\hat{\kappa}_B) = \frac{1}{B}\sum_b (\hat{\kappa}_b - \hat{\kappa}^B)^2$ and $V(\hat{\sigma}_B) = \frac{1}{B}\sum_b (\hat{\sigma}_b - \hat{\sigma}^B)^2$. The estimated covariance of $\hat{\kappa}$ and $\hat{\sigma}$ is calculated analogously. In particular, bootstrap estimation does not rely on matrix inversion for the calculation of the covariance matrix.

3. Robustness

This section focuses on the robustness to the adoption cost with a logit specification of the adoption costs instead of the probit. Table 2 provides a summary of the results. Overall, we find that the estimates do not differ quantitatively or qualitatively from the probit function. Figure 1 illustrates the sensitivity analysis on the discount factor using the logit function.

4. Variable List

The list of variables used in this study is summarized in Table 3.

References

Lippi, F., and A. Secchi (2009): "Technological change and the households' demand for currency," *Journal of Monetary Economics*, 56(2), 222–230.

Table 2: **Adoption Cost Structural Estimates**

CELL	COH	EDU	REG	$\bar{c}^*$	Log utility $\hat{\kappa}$	Log utility Δc	CRRA utility $\hat{\kappa}$	CRRA utility Δc
1	1	1	1	15,224	29.6	4,906	6.7	15,220
2	1	1	3	16,694	34.1	5,748	15.2	16,690
3	1	1	4	13,741	18.7	6,736	1.2	13,738
4	1	3	1	18,568	29.1	4,671	12.8	18,561
5	1	3	3	19,460	33.6	5,990	24.9	13,619
6	1	3	4	17,466	18.1	7,045	5.1	17,462
7	1	4	1	24,872	35.0	1,821	26.0	5,707
8	1	4	3	25,642	40.4	3,503	45.1	7,680
9	1	4	4	25,411	23.3	6,463	13.0	25,404
10	2	1	1	21,151	31.7	4,772	13.4	21,145
11	2	1	3	22,249	36.7	6,567	25.8	22,244
12	2	1	4	17,321	20.6	6,709	5.3	17,318
13	2	3	1	22,601	32.1	3,142	21.9	22,592
14	2	3	3	25,194	37.3	5,060	39.4	25,188
15	2	3	4	20,464	20.9	6,172	10.6	20,459
16	2	4	1	28,643	38.4	(690)	41.4	24,957
17	2	4	3	30,631	44.4	1,057	70.9	30,614
18	2	4	4	25,917	26.3	3,938	22.6	25,908
19	3	1	1	20,002	42.2	3,575	20.6	19,996
20	3	1	3	24,597	47.4	5,555	36.6	24,592
21	3	1	4	17,480	31.1	5,501	10.0	17,476
22	3	3	1	20,458	47.8	2,126	34.7	20,449
23	3	3	3	23,032	52.7	4,204	58.3	23,025
24	3	3	4	15,707	34.1	4,308	18.0	15,702
25	3	4	1	23,196	55.2	(1,190)	62.0	—
26	3	4	3	27,227	61.3	(476)	101.6	27,211
27	3	4	4	21,118	39.7	3,320	34.1	21,110
	Overall			19,584	32.5	4,429	21.3	17,870

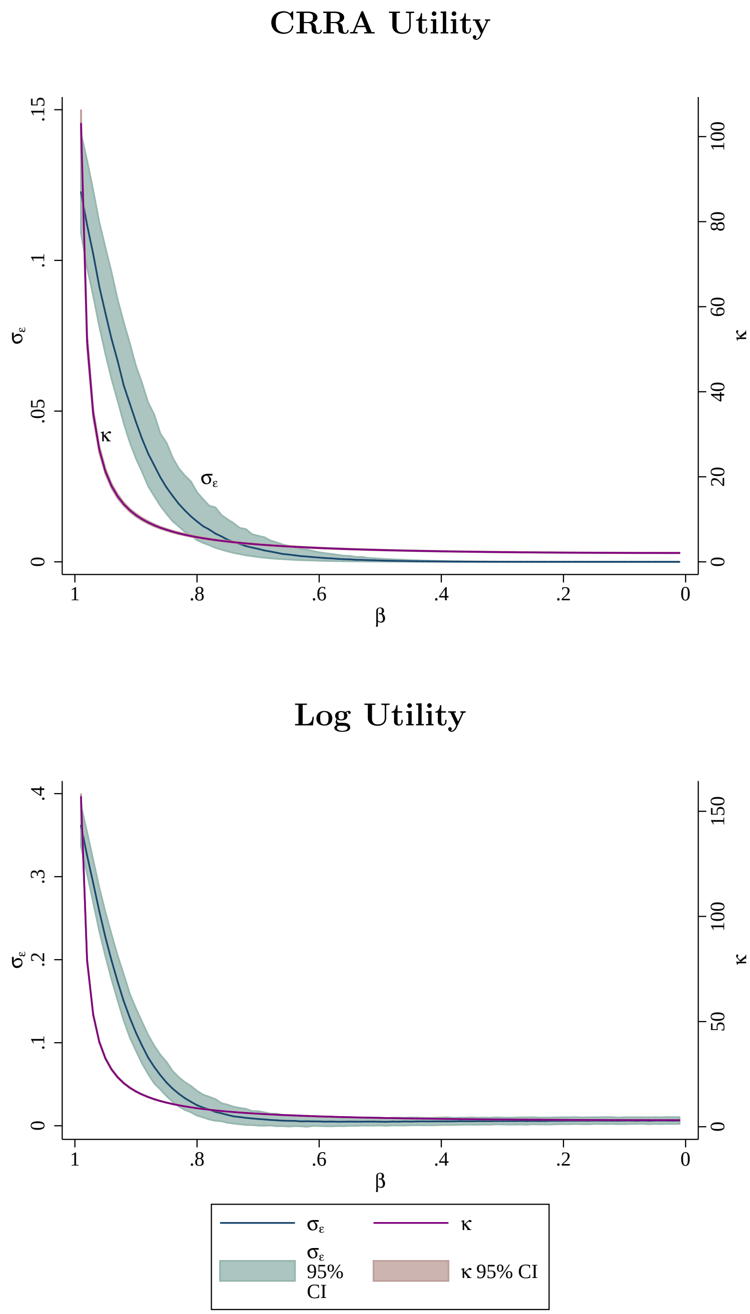
Note: The discount factor is 0.95 for both utility functions. The estimated standard deviation of the shock to the adoption probability, $\hat{\sigma_\epsilon}$, is 0.42 and 0.15 for log and CRRA utility, respectively. The $\hat{\kappa}$ and adoption costs (Δc) are computed for 27 cells for three age cohorts (COH): 1 (Birth year of 1936 or earlier), 2 (Birth year of 1937 to 1950), and 3 (Birth year of 1951 or later); three education categories (EDU): 1 (Primary or less), 3 (Secondary), and 4 (Post-secondary and above); and three regional groups (Reg): 1 (North), 3 (Centre), and 4 (South and Islands). The within cell mean non-durable consumption ($\bar{c}^*$) and Δc are are provided in €2004. Brackets contain quantities estimated to be negative. An em-dash (—) means that choice probabilities could not be inverted.

Table 3: Variable Description

Variable	Definition
m*	Cash holding
lm	logarithm of cash holdings
c*	non-durable consumption
lc	Logarithm of consumption
w*	financial wealth
log w_defl	Logarithm of wealth deflated
pesofit*	respondent weight
anno	Year
eta	Age
eta2	Age Squared
normalized birthyear	(Year - Age - 1875)/100
male	Male
empl	Employed
selfempl	Self-employmed
stu1	No Schooling
stu2	Elementary School
stu3	Middle School
stu4	High School
stu5	College
totadul	Number of Adults
totchil	Number of Children
ubic1	Countyside
ubic2	Town outskirts
ubic3	Suburbs
ubic4	City Centre (Excluded category)
area_dum1	North-West
area_dum2	North-East
area_dum3	Centre (Excluded category)
area_dum4	South
area_dum5	Islands
bancomat	ATM card indicator
bank_pop_city	Regional bank density (number bank branches/1000 persons)
r	Regional nominal deposit rate
lr	Logarithm of nominal deposit interest rate
π	Inflation
log (π)	Logarithm of inflation rate
real	Constructed from regional nominal deposit rate and inflation
log (real)	Logarithm of real interest rate

Notes: Most of the data series are taken from the replication files of Lippi and Secchi (2009) with the exception of those in *. These variables were extracted directly from the finvars.dta data file from the Banca d'Italia website: `https://goo.gl/hhxa3K`

Figure 1: **Sensitivity of Adoption-Cost Estimates to the Discount Factor**



Note: This figure illustrates the the median parameter estimates and the 95 percent confidence intervals (based on 1000 bootstrap samples) of $\hat{\sigma}_\epsilon$ (blue, left vertical axis) and $\hat{\kappa}$ (green, right vertical axis) versus the value of the discount factor, β (horizontal axis).