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Addressing a challenge to monetary policy models

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Document de travail

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Abstract

Despite some strong cases built against it, the Euler equation on consumption remains a cornerstone of monetary policy models.

In this paper I test the representative household's consumption-savings trade-off in two original directions. I first use households' specific interest rates for both US and France. These rates have a better explanatory power of the representative consumer's behaviour than the monetary policy rate. I also use a less restrictive approach to measure households' expectations based on survey data.

However, the challenge posed by the Euler equation to monetary policy models remains.

Keywords: Euler equation, consumption

L'équation d'Euler est morte, vive l'équation d'Euler !

Résumé

Malgré des éléments à charge conséquents, l'équation d'Euler sur la consommation reste une des briques élémentaires des modèles de politique monétaire.

Dans cet article je teste l'arbitrage consommation-épargne du ménage représentatif dans deux directions nouvelles. J'utilise des taux d'intérêt spécifiques aux ménages pour les États-Unis et la France. Ces taux améliorent la description du comportement de l'agent représentatif comparativement au taux de la politique monétaire. Je mesure également différemment les anticipations des ménages à partir d'enquêtes de conjoncture.

Malgré cela, le challenge posé par l'équation d'Euler aux modèles de politique monétaire reste entier.

Mots-clés : équation d'Euler, consommation

Classification JEL : E21, D91

Introduction

The Euler equation on consumption is a cornerstone of monetary policy models. In the permanent income hypothesis, when households are assumed to be rational, their consumption scheme should verify the following equation:

$$1 = \beta E_t \left(\frac{U_c(t+1)}{U_c(t)} \frac{1+i_t}{\Pi_{t+1}} \right) \tag{1}$$

where $U_c(t)$ is the marginal utility of consumption at time t, i is the nominal interest rate at which households can lend and borrow and Π the inflation rate of consumption prices. E_t is the expectation operator describing how households form their expectations over future variables at time t.

Since Hall (1978), macroeconomic data have been confronted to economic theory repeatedly leading to successive refutations, validations and improvements in households' consumption models. Early papers, surveyed by Attanasio (1999), have investigated the properties of consumption within this framework under the assumption of constant real interest rate and often certainty equivalence. Many alternative utility functions have been used to reconcile consumption data with the permanent-income hypothesis and understand some major stylized facts. Mankiw (1982), and Bernanke (1985) study the specificities of durables consumption. Abel (1990) and Gali (1994) investigate the equity premium puzzle by modifying the utility function. Campbell and Mankiw (1990) consider a population with only a fraction of households following the model, while others, financially constrained, consume their current income in each period. Flavin (1981) investigates the *excess sensitivity puzzle*, that is consumption reacting to lagged changes in income. Campbell and Deaton (1989) investigate the *excess smoothness puzzle*, that is consumption not responding one-to-one to shocks to permanent income.

Relaxing the constant interest rate hypothesis Canzoneri et al. (2007) test the first order condition of households maximization program (1) under different utility specifications against the data. Their main result is that when the Euler equation is assumed to hold and the interest rate is treated as the unknown variable, the counter-factual interest rate to which the representative household seems to respond is quite different from the monetary policy rate. In most cases it is negatively correlated to it, a result they pose as a *challenge for monetary policy models*, which are built on this Euler equation to link the real and nominal side of the economy.

To derive these results, they assume that households' expectations can be described through a VARX model, i.e. households use optimally all the information publicly available. This hypothesis combined either with a log-normality hypothesis or a first order approximation allows them to estimate the marginal rate of substitution between present and future consumption which, if the Euler equation was verified by the data, should be equal to the interest rate faced by households. They compare this marginal rate of substitution with the actual monetary policy interest rate and doing so invalidate the permanent income hypothesis even when many alternative utility functions are considered.

Carroll (2000) would interpret this result as an incompatibility between macro data and a microfounded model, due to the differences in the marginal behaviour of individuals. The Euler equation on consumption could be wrong, not because of the form of the utility function but because the representative agent assumption is heroic. However, microeconomics comes against its own difficulties (Carroll, 2001; Ludvigson and Paxson, 2001) while macroeconomic models remain widespread and have crucial implications for the policy maker, both monetary and fiscal. Thus, the *challenge* posed by the aggregate Euler equation on consumption is worth investigating.

I built on Canzoneri et al.'s analysis and test household specific rates in an estimated Euler equation for both the US and France when expectations are measured *ex ante* by a VARX model. I find that households' behaviour is better described by interest rates other than the monetary policy one; indicating that households encounter sizeable frictions on the loans and savings market.

Specifically, I find that the Euler equation is compatible with households reacting to the rate on car loans in the US; but for France households do not seem to react to any specific rates. These results have strong implications for the conduct of monetary policy: the transmission channel is much weaker than generally assumed; and for economic modelling: the spread between household market conditions and the monetary policy instrument can not be relegated to the residual.

Even for the US, there remain sizeable discrepancies between the Euler equation and the data. In particular households seem to react to an interest rate much more volatile than actual rates, a property I will investigate further in the remainder of this project.

1 Testing the Euler equation against household specific interest rates

Using macroeconomic data to capture the value of structural parameters is not the purpose of this paper: Attanasio and Weber (1993) show that estimates of the intertemporal elasticity of substitution on aggregate data are systematically lower than estimates on average cohort data. Attanasio and Weber (1993, 1995) show that tests on aggregate data tend to reject micro-founded models specification too often. Carroll (2000) actually wrote a *requiem for the representative consumer model* on the idea that individual wealth heterogeneity imply marginal utility heterogeneity and potentially impossible aggregation of the Euler equation. However as this model still prevails in macroeconomics, **I inquire into how much of the Euler equation can be saved by a richer dataset.**

Canzoneri et al. (2007) test and reject the Euler equation on consumption on US data.[1] They describe the failure of Euler equation as follows: "*the consumption Euler equation implies that the real interest rate is proportional to the expected growth of real consumption. The empirical literature shows that a monetary tightening has a small effect on consumption in the first quarter following the tightening. In the following few quarters, the consumption falls more rapidly so that expected consumption growth declines. A decline in expected consumption growth will reduce the real interest rate implied by the Euler equation. The empirical literature shows that money market rates respond in the opposite direction.*"

However, if households were reacting to another interest rate than that of the money market (mortgage, deposit, private loans...), the difference between this rate and monetary policy could account for the negative or weak correlation they observe. Such a result would have strong implications for monetary policy analysis and the way it is modelled (in the New Neoclassical Synthesis for instance). It would rehabilitate the Euler equation but dampen the transmission mechanism between the policy maker and households.

In this paper, I investigate this possibility. I estimate the relation between different household specific interest rates, expected consumption growth and expected inflation and assess the significance of interest rates in this equation and the fit to the data. The interest rates I consider are depicted on Figure 1. The correlation of real monetary policy rate and the spreads on household specific rates are reported in Table 1. It is noteworthy that household specific spreads are negatively correlated to real monetary policy rate, which could *a priori* account for the results exposed by Canzoneri et al. (2007).

US rates (Figure 1a) I use the Effective Federal Funds Rate (Fedfunds), a mortgage rate *(30-Year conventional mortgage rate)*, a car loans rate *(Finance Rate on Consumer Instalment Loans at Commercial Banks, New Autos 48 Month Loan)*, a personal loans rate *(Finance Rate*

[1] In appendix C I replicate their results. I show that they also hold on French data. While they tested the robustness to the definition of the utility function considered, I show that the result is also robust to the choice of several consumption bundles.

real FedFunds	1	-	-	-	-	-
spread Mortgage	-0.3	1	-	-	-	-
spread Car Loans	-0.43	0.91	1	-	-	-
spread Pers. Loans	-0.46	0.84	0.88	1	-	-
spread Cert. Deposit	-0.2	0.38	0.35	0.38	1	-
spread Treasury Bill	-0.46	0.73	0.76	0.84	0.52	1

(a) US

real Pibor	1	-	-	-
spread Deposit1y	-0.5	1	-	-
spread Livret	-0.83	0.57	1	-
spread Mortgage	-0.11	0.51	0.33	1

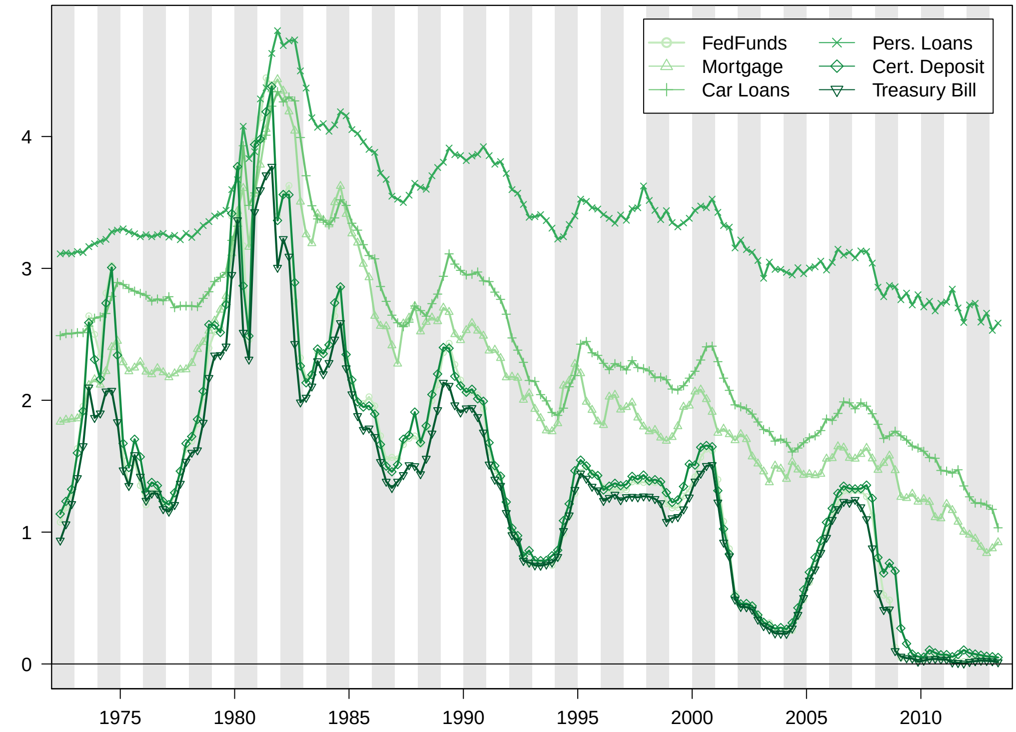
(b) France

Table 1: Correlation of the interest rates (in real terms)

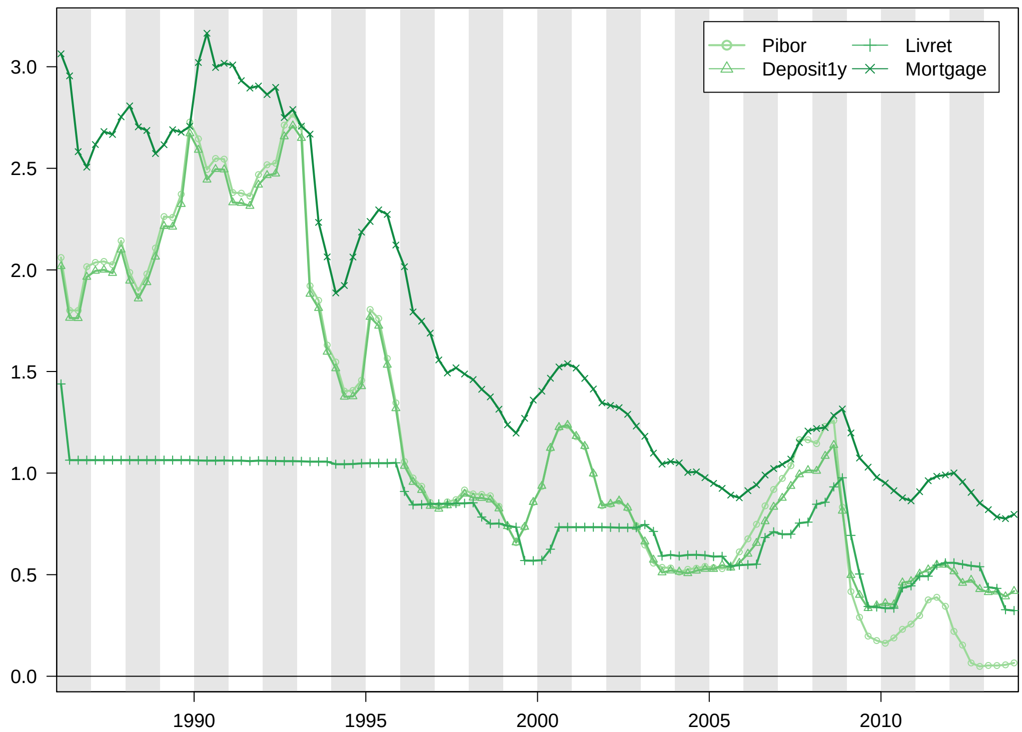
on Personal Loans at Commercial Banks, 24 Month Loan), a deposit rate *(3-Month Certificate of Deposit: Secondary Market Rate)* and the 3-month treasury bill *(3-Month Treasury Bill: Secondary Market Rate)*. Apart from the mortgage rate, maturities of these interest rates are short. The mortgage rate is included because wealth effects are empirically stronger in the US than in France, a stylized fact sometimes attributed to the higher flexibility of mortgages in the US where real estate can be used as a collateral for consumption (Aviat et al., 2007). Some of these rates are closely related (treasury bill, fedfunds and certificates of deposits). I keep them all to remain as exhaustive as possible.[2]

French rates (Figure 1b) I use the 3-month interbank rate (Pibor-Euribor) and three different rates, all for new contracts for households and individual enterprises: *Deposits with agreed maturity* up to one year, *Deposits redeemable at notice* and *Loans for house purchases excl. bank overdrafts*, total maturity. *Deposits redeemable at notice* refer to regulated savings accounts. The oldest one (*livret A*) dates back to the nineteenth century and is the most widespread financial product in France: more than 90% of French residents have such an account, standing with other *livrets* (*livret jeune, livret developement durable, livret d'épargne populaire*) for more than 15% of French households' financial assets (Noyer and Mérieux, 2012). As shown on Figure 1b the return on these savings is not linked to the monetary policy rate on most of the sample. More recently, this rate has been indexed on a combination of inflation, Eonia and Euribor with a discretionary component set by the government.[2]

[2] Data are further detailed in appendix A.1.



(a) United States



(b) France

Figure 1: Actual interest rates in nominal terms

The Euler equation under a linear form I assume that households are forming their expectations through a VARX model estimated ex-ante.

$$c_{t+1} = \sum_{j=0}^{k} \lambda_j^{c,c} c_{t-j} + \sum_{j=0}^{k} \lambda_j^{c,\pi} P_{t-j} + \gamma^c X_t + \epsilon_{t+1}^c \tag{2}$$

$$P_{t+1} = \sum_{j=0}^{k} \lambda_j^{\pi,c} c_{t-j} + \sum_{j=0}^{k} \lambda_j^{\pi,\pi} P_{t-j} + \gamma^\pi X_t + \epsilon_{t+1}^\pi \tag{3}$$

$$\tag{4}$$

with c consumption per capita (in log) and P its deflator (in log) regressed on 12 lags of both variables and on exogenous regressors (X). For these regressors I consider alternatively economic variables, following Canzoneri et al. (2007) and Fuhrer (2000), and balances of opinion from household surveys. In this latter case, I use the surveys of consumers by the university of Michigan and the European harmonized household survey published for France by Insee (see also Appendix A.2). This second method is less biased by the economist's *a priori*, however I find very similar results with these data. ϵ^c, ϵ^π are the errors of this VARX model and are by assumption identified to forecasting errors.

If the Euler equation holds, the following should hold under log-normality hypothesis of the VARX residuals (see Appendix B):

$$i_t = \sigma E_t \Delta c_{t+1} + E_t \pi_{t+1} - ln(\beta) - \left(\frac{\sigma^2}{2} var(\epsilon^c) + \sigma cov(\epsilon^c, \epsilon^\pi) + \frac{1}{2} var(\epsilon^\pi) \right) \tag{5}$$

with i_t the interest rate to which households are subject and $E_t \Delta c_{t+1}$, $E_t \pi_{t+1}$ the expectations formed through the previous VARX model for consumption growth (Δlog) and inflation.[3]

Model estimation Using several interest rates in an agnostic way, the model can be tested under the following form:

$$E_t \Delta c_{t+1} = \delta + \sum \gamma^x \left(i_t^x - E_t \pi_{t+1} \right) + \varepsilon_t \tag{6}$$

with a constant (δ), coefficients (γ^x) and errors (ε) to be estimated.

For sake of comparability, I estimated the model only with the monetary policy rate and I accept the hypothesis that this rate alone does not bring useful information in explaining expected consumption growth. This result summarizes those of appendix C as raising a challenge for monetary policy models using the Euler equation: this equation, as it is used in monetary policy models, is at odds with the data. The estimates for equation (6) with household specific rates are reported in Table 2.

[3] Inflation is defined in accordance with consumption as the growth rate (Δlog) of the considered consumption bundle deflator.

	Economic Regressors		Surveys	
	coeff.	Std.	coeff.	Std.
cste	0.0073	4.8645	0.0078	3.6757
r.FedFunds	-0.3038	-1.2174	-0.4877	-1.3654
r.Mortgage	-0.0105	-0.084	-0.0083	-0.0476
r.Car Loans	0.6231	4.7107	0.5532	2.9457
r.Pers. Loans	-0.4071	-5.1623	-0.3887	-3.4573
r.Cert. Deposit	-0.9478	-3.4824	-0.9392	-2.4075
r.Treasury Bill	1.1787	5.0743	1.4423	4.3088
DW/adjustedR2	0.9283	0.3568	1.1059	0.228
	stat.	p-value	stat.	p-value
Fisher's Test 1	16.07	0	9.02	0
Fisher's Test 2	13.9	0	14.03	0
Fisher's Test 3	19.18	0	10.5	0
Fisher's Test 4	0.23	0.98	0.13	1

(a) US

	Economic Regressors		Surveys	
	coeff.	Std.	coeff.	Std.
cste	9e-04	1.1216	9e-04	0.8961
r.Pibor	0.5817	2.0315	0.756	2.2445
r.Deposit1y	-0.9067	-2.5547	-1.1223	-2.7031
r.Livret	-0.2059	-1.8859	-0.1854	-1.5661
r.Mortgage	0.3896	2.6083	0.414	2.3809
DW/adjustedR2	1.4493	0.0814	1.9567	0.0756
	stat.	p-value	stat.	p-value
Fisher's Test 1	2.25	0.04	2.13	0.06
Fisher's Test 2	2.71	0.1	2.43	0.12
Fisher's Test 3	2.38	0.04	2.38	0.04
Fisher's Test 4	0.05	1	0	1

(b) France

Table 2: Euler equation models (6) (CES utility function with expectations measured by a VARX with economic regressors or survey data)

For the US (Table 2a), coefficients are significantly different from 0, excepted for the fedfunds and the rate on mortgages. The signs of the estimated coefficients are nevertheless economically puzzling: for instance, the interest rate on car loans and personal loans have opposite effects on consumption. Overall this estimation yields a negative rate combination in nominal terms which is at odds with the theory.

For France (Table 2b), the coefficient on the regulated savings rate is not statistically significant.[4] Similarly to the US, the signs of the coefficients vary, which is not economically interpretable and the optimal rate combination is largely negative.

Are these *Euler equations on consumption*? On this model I perform three Fisher's tests examining whether the estimated equation can be called *Euler equation on consumption* in which household specific rates play a role:

$\mathcal{T}_1$ on the joint nullity of all coefficients as a simple check

$\mathcal{T}_2$ on the cumulated nullity of interest rate coefficients to verify that this model effectively relates expected consumption with interest rates so that it can be called a *Euler equation on consumption*

$\mathcal{T}_3$ on the joint nullity of interest rate coefficients (other than monetary policy) to verify that rates other than the monetary policy one bring useful information to the model

$\mathcal{T}_4$ on the equality between coefficients estimated using the expectation VAR and assuming perfect expectations

These tests are reported in Table 2. For the US countries all null hypothesis but the last are rejected. For France, only at the 10% threshold can I reject the hypothesis that $\sum_x \gamma^x = 0$.

[4]The constant is not significantly different from 0 either: in equation (6) $ln(\beta)$ and the variance term are of opposite sign and can add up to zero.

The first three tests imply that the estimated equation is a *Euler equation on consumption* in which household specific rates play a role.

As for the last test, it is conducted to verify how the VARX estimated *ex ante* influences the estimation in this second step. The test concludes that the two estimations are not statistically different.

Interest rates comparisons From equation (6), the previous Fisher's tests allow me to compute

$$\frac{E_t \Delta c_{t+1} - \delta}{\sum_x \gamma^x} + E_t \pi_{t+1} \quad \text{and} \quad \frac{\sum_x \gamma^x i_t^x}{\sum_x \gamma^x} \tag{7}$$

The left hand side of the previous equation is the marginal rate of substitution between present and future consumption (hereafter *MRS* denoted $\tilde{i}_t$).

$$\tilde{i}_t = \frac{E_t \Delta c_{t+1} - \delta}{\sum_x \gamma^x} + E_t \pi_{t+1} \tag{8}$$

If the model held exactly, this rate would be equal to the optimal combination of actual rates returned by the estimation $\bar{i}_t$

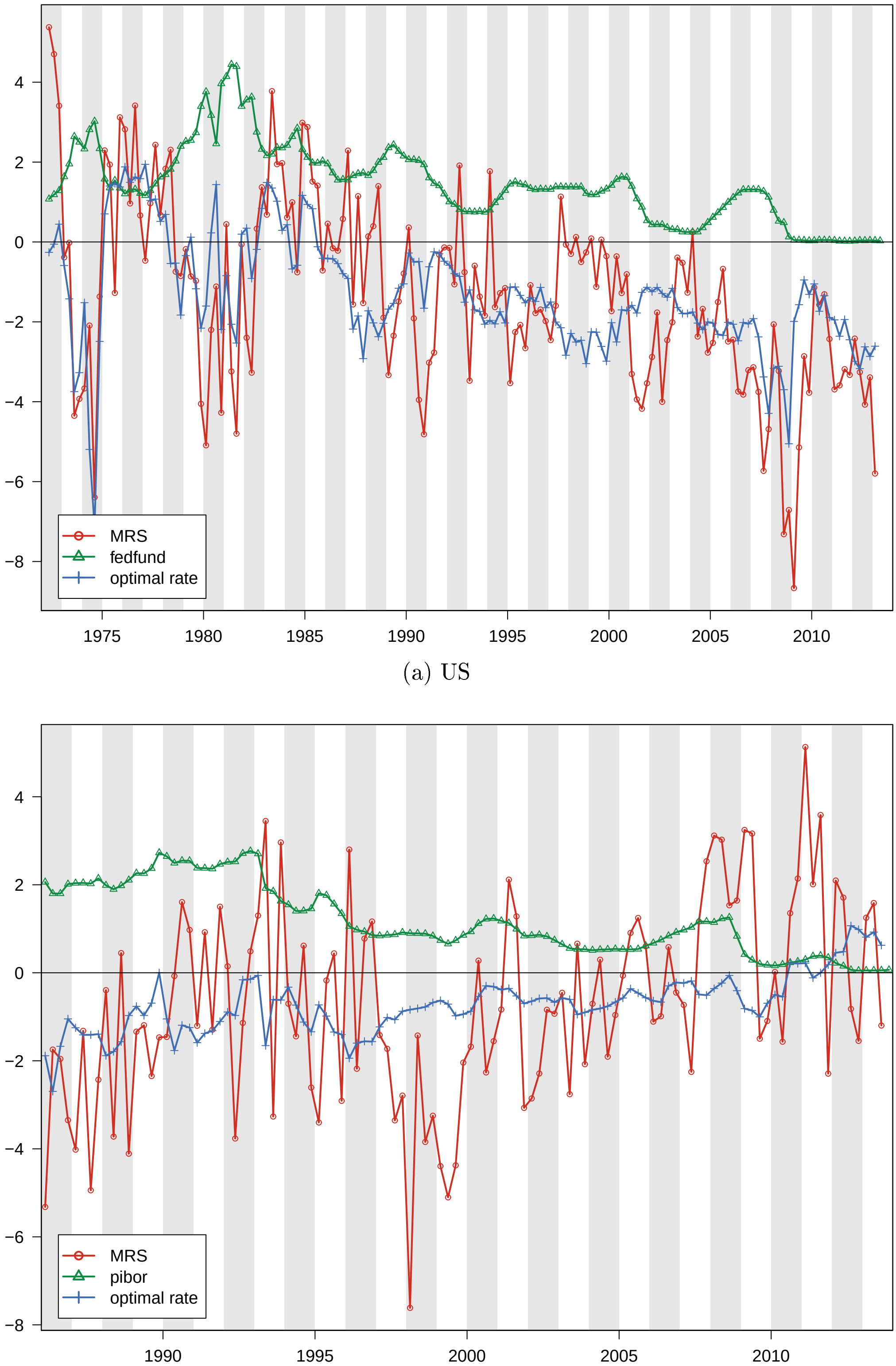
$$\bar{i}_t = \frac{\sum_x \gamma^x i_t^x}{\sum_x \gamma^x} \tag{9}$$

Table 3 displays some comparative statistics for actual and Euler interest rates in real terms.

In the US, the *MRS* is not correlated with the Fedfunds ($< 10\%$). The correlation with the optimal rate combination is much larger (62%). For France, correlation with the Pibor-Euribor can even be negative. With the optimal spread combination it reaches 34% when deflation is based on expected future inflation (correlations 2).

However for both countries, the statistical properties of both the optimal rate combination and the *MRS* are not consistent with the initial interest rates. In particular, they are negative and the *MRS* is much more volatile than the corresponding optimal rate combinations (Table 3). Comparisons of theses rates depicted in Figure 2 convey the same message.

I find similar results when expectations are built on survey data. Also allowing for autocorrelation of the residual and habit formation in the utility function does not markedly modify the outcome of the estimations.



(a) US

(b) France

Figure 2: Actual interest rates and *MRS* with a CES utility function (in nominal terms)

	Fedfunds i^{x_0}	Opt. Comb. $\bar{i}$	MRS $\tilde{i}$
Mean	0.46	-2.32	-2.31
Std deviation	0.72	1.48	2.35
Minimum	-0.93	-9.63	-9.15
Maximum	2.76	0.83	4.5
Correlation1	1	0.13	0.08
Correlation1	0.13	1	0.62
Correlation2	1	0.08	0.05
Correlation2	0.08	1	0.62

(a) US

	Pibor i^{x_0}	Opt. Comb. $\bar{i}$	MRS $\tilde{i}$
Mean	0.71	-1.2	-1.2
Std deviation	0.73	0.79	2.32
Minimum	-0.5	-3.19	-7.81
Maximum	2.52	0.96	4.36
Correlation1	1	-0.33	-0.18
Correlation1	-0.33	1	0.28
Correlation2	1	-0.35	-0.12
Correlation2	-0.35	1	0.34

(b) France

I test two transformations of actual nominal rates in real terms: correlation 1 corresponds to the rate deflated by contemporaneous inflation $i_t - \pi_t$ and correlation 2 uses expected future inflation $i_t - E_t\pi_{t+1}$.

Table 3: Comparative statistics of the interest rates and the *MRS* (in real terms)

Positivity constraint Under a simplifying aggregation assumption, one could expect the weight of each rate in the optimal combination to be the share of the population arbitrating on it, so that $\forall x$ the sign of γ^x is the same as the sign of the intertemporal elasticity of substitution. The high correlations from the previous unconstrained estimations and the lack of economic interpretation of the optimal combinations found may thus be a statistical artefact. In line with this intuition I estimate the same model by maximum likelihood while restricting the sign of γ^x. These constrained estimations allow me to select a subsample of interest rates for which the restriction is verified. Results are reported in Table 4.

For the US the selected model includes only the rate on car loans. Its coefficient in the regression is significantly different from 0 so I can compute the *MRS* in this case. The correlation of the *MRS* with the optimal rate combination (equal to the car loans rate) is however weakened compared to the unconstrained estimation (see Table 5). Comparisons of theses rates are depicted in Figure 3. The *MRS* is in particular very volatile.

For France, the selected model includes only the rate on mortgages but its coefficient in the regression is not significantly different from 0. Only for sake of comparison with the US are the results presented in the case of France in Table 5 and Figure 3.

	Economic Regressors		Surveys	
	coeff.	Std.	coeff.	Std.
cste	0.0019	3.2915	0.0017	2.3078
r.FedFunds	0	0	0	0
r.Mortgage	0	0	0	0
r.Car Loans	0.1588	4.3575	0.1734	3.8721
r.Pers. Loans	0	0	0	0
r.Cert. Deposit	0	0	0	0
r.Treasury Bill	0	0	0	0
DW/adjustedR2	0.7677	0.0994	0.943	0.079

(a) US

	Economic Regressors		Surveys	
	coeff.	Std.	coeff.	Std.
cste	0.0019	3.0473	0.002	2.8127
r.Pibor	0	0	0	0
r.Deposit1y	0	0	0	0
r.Livret	0	0	0	0
r.Mortgage	0.0626	1.4635	0.0519	1.0583
DW/adjustedR2	1.2403	0.0103	1.725	0.0011

(b) France

Reported values for the interest rate coefficients are the γ^x, not the λ^x. The variance matrix for the estimates is computed with the delta method and from the gradient of the likelihood at each date.

Table 4: Euler equation models (6) under positivity constraint (CES utility function with expectations measured by a VARX with economic regressors or survey data)

	Fedfunds i^{x_0}	Opt. Comb. $\tilde{i}$	MRS $\tilde{i}$
Mean	0.46	1.45	1.46
Std deviation	0.72	0.69	1.97
Minimum	-0.93	-0.6	-4.25
Maximum	2.76	3.32	7.15
Correlation1	1	0.81	0.08
Correlation1	0.81	1	0.34
Correlation2	1	0.79	0.05
Correlation2	0.79	1	0.32

(a) US

	Pibor i^{x_0}	Opt. Comb. $\tilde{i}$	MRS $\tilde{i}$
Mean	0.71	1.22	1.23
Std deviation	0.73	0.75	5.23
Minimum	-0.5	-0.19	-11.3
Maximum	2.52	2.9	16.16
Correlation1	1	0.95	0.18
Correlation1	0.95	1	0.19
Correlation2	1	0.94	0.12
Correlation2	0.94	1	0.14

(b) France

I test two transformations of actual nominal rates in real terms: correlation 1 corresponds to the rate deflated by contemporaneous inflation $i_t - \pi_t$ and correlation 2 uses expected future inflation $i_t - E_t\pi_{t+1}$.

Table 5: Comparative statistics of the interest rates and the *MRS* under positivity constraint (in real terms)

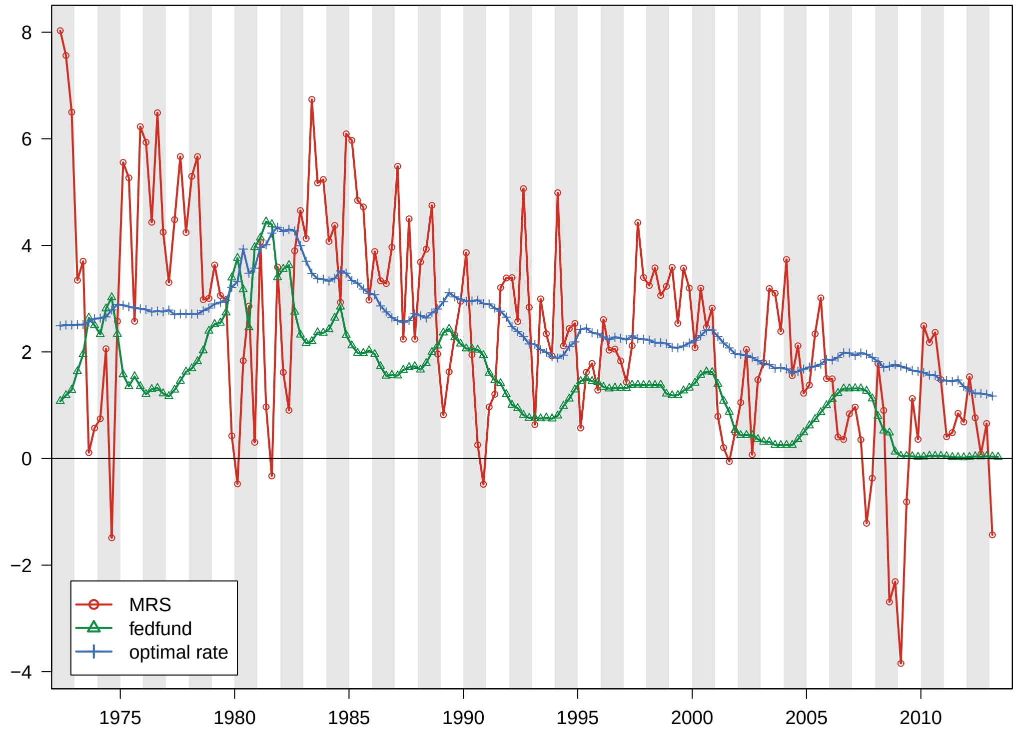
Conclusion

The monetary policy rate does not bring useful information to explain the intertemporal elasticity of substitution of consumption of the representative consumer both in the US and France. This paper points to a representative household reacting to the interest rate on car loans in the US. For France this rate is not identified.

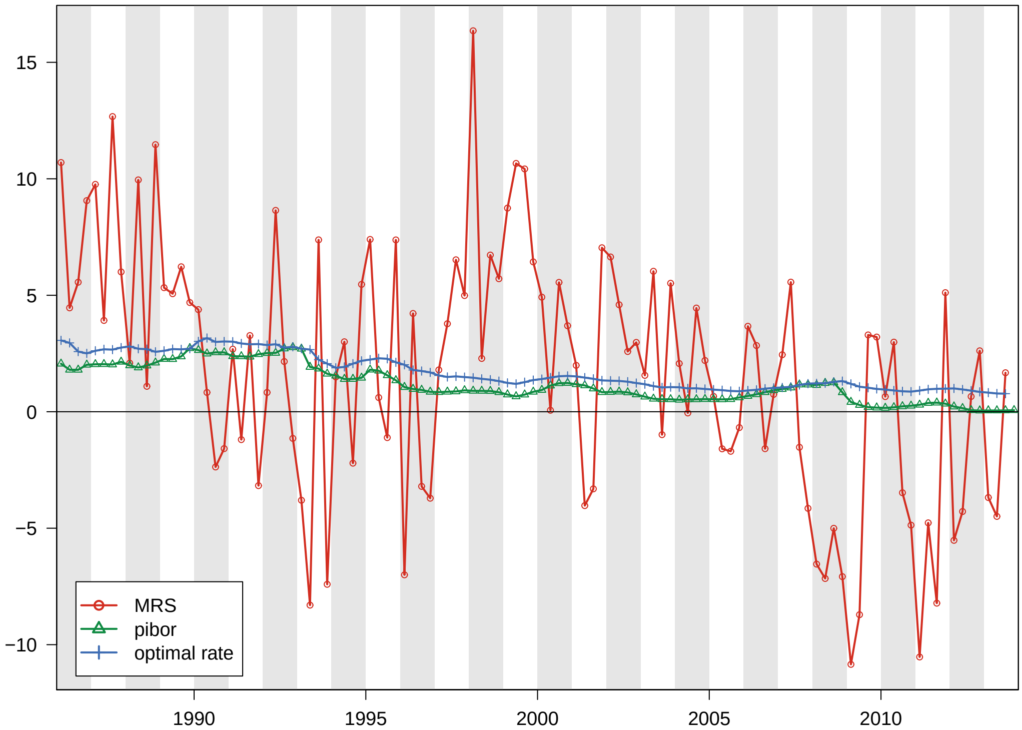
This result may seem trivial as it is clear that households can not borrow directly from the Central Banker's desk. What is less trivial however, is that the spread between households' rate and the monetary policy instrument matters so much and shall not be relegated to the residual of the Euler equation. Models should account for financial market frictions faced by households and consider weaker transmission mechanism of the monetary policy to a major share of real final demand, households' consumption.

Household specific rates explain part of the wedge between the *MRS* and the monetary policy rate in the US; however there remain sizeable discrepancies which do not rehabilitate the Euler equation as a powerful modelling element. In other words, the challenge to monetary policy models raised by Canzoneri et al. (2007) remains unchanged.

This dead-end may be due to omitted variables (current income, demographic effects, unemployment...) in the Euler equation under its simplest form. Indeed, econometric investigations of the consumption-savings behaviour often put forward richer specifications (Aviat et al., 2007; Bardaji et al., 2014). In the present paper I find that the *MRS* is extremely volatile. Similar estimations as those presented in this paper with habit formation suggest that allowing the utility of consumption to be smoother does not reduce the volatility of the *MRS*. In further developments of this project, I will investigate the extend to which the measurement of expectations used can influence this result.



(a) US



(b) France

Figure 3: Actual interest rates and *MRS* with a CES utility function under positivity constraint (in nominal terms)

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A Data and the VAR of expectations

A.1 Data

France I use Insee's Quarterly National Accounts data for consumption per capita excluding durables, its deflator, GDP, disposable income.[5] Data, including interest rates, are available since the early eighties but I restrict the sample to post 1986 for stationariness reasons as this sample includes only the end of the period of high and volatile inflation. Interest rate (Pibor-Euribor and household specific rates) are taken from Banque de France and the ECB. For household balances of opinion, I use the European harmonized Household Survey published for France by Insee. Population and unemployment data are also retrieved from Insee's public database. I use

[5] Data are taken from the first publication of base 2010 (2014Q1) but I also estimated with similar results the model on the last publication of base 2005.

quarterly data spanning from 1986Q1 to 2013Q4.

US I use data from the National Income and Product Account(NIPA)for consumption, GDP, disposable income and deflators. I restrict consumption to non-durable goods and services. Real variables are taken per-capita. Interest rates, population and unemployment data are taken from the Fred database. I also use the surveys of consumers by the university of Michigan. I use quarterly data spanning from 1972Q1 to 2013Q2.

A.2 The VAR of expectations

For section 1 and appendix C, I estimate a VARX to model households' expectations. This method is based on Fuhrer (2000) and Canzoneri et al. (2007). I restricted the specification of the expectation VAR to a VAR in level with 12 lags. However, I show in appendix C that the rejection of the Euler equation does not depend on the choice of a VAR model.

US I estimate a VAR model corresponding to the log of consumption in non-durables per capita and its deflator. I replicate the VARX of Fuhrer (2000) and Canzoneri et al. (2007) to model households' expectations in the US: additional regressors are the fedfund rate, log GDP and log GDI per capita. However, I do not use the Journal of Commerce industrial materials commodity price index for all items and tested some balances of opinion from the Michigan survey without significant modifications.

I also estimate expectations from a VARX using only balances of opinion from the Michigan survey: the Index of Consumer Expectations, Index of Current Economic Conditions and balances of opinion related to financial situation (past and expected), oppportunity to purchase durables, vehicles or a house, and expected inflation in the next 12 months.

France I estimate a VAR model corresponding to the log of consumption in non-durables per capita and its deflator. This VAR model also contains 12 lags and is estimated from 1986Q1 to 2013Q4 in level. To this VAR I add the lags of the purchasing power of gross disposable income, of GDP per capita, the Pibor-Euribor and test some balances of opinion from household opinion survey which do not significantly impact the outcome of the VAR.

I also estimate expectations from a VARX using only balances of opinion from the European harmonized consumers survey: general economic situation, unemployment, financial situation, consumer prices, savings intentions, current saving capacity.

B The conditional log-normality hypothesis

The equation under scrutiny takes the following form:

$$(1+i_t)^{-1} = \beta E_t\left(\frac{U_c(t+1)}{U_c(t)}\frac{1}{\Pi_{t+1}}\right) \tag{10}$$

In the most simple case $U_c(t) = C_t^{-\sigma} = e^{-\sigma c_t}$ with $c_t = log(C_t) \quad \pi_t = log(\Pi_t)$

$$E_t\left(\frac{U_c(t+1)}{U_c(t)}\frac{1}{\Pi_{t+1}}\right) = E_t(exp(-\sigma\Delta c_{t+1} - \pi_{t+1})) = E_t(exp(a'y_{t+1})) \tag{11}$$

with $a = [-\sigma, -1]'$ and $y_t = [\Delta c_t, \pi_t]'$.

I suppose that households' expectations are formed through the previous VAR model with normal errors ν_t and variance Σ, so that $y_{t+1} = E_t(y_{t+1}) + \nu_{t+1}$. I can then decompose $E_t exp(a'y_{t+1}) = exp(a'E_t y_{t+1})E_t exp(a'\nu)$, in which the second term can be simplified

$$E_t exp(a'\nu) = \int \frac{1}{(2\pi)^{\frac{n}{2}}|\Sigma|^{\frac{1}{2}}} \exp\left(a'\nu - \frac{1}{2}\nu'\Sigma^{-1}\nu\right) d\nu$$

first change of variables

$$\Sigma^{-1} = P'DP \quad \text{with} \quad P \in \mathcal{O}(n) \quad \text{and} \quad D \quad \text{diagonal}$$

$$P\nu = \mu$$

$$\nu = P'\mu$$

$$E_t exp(a'\nu) = \int \frac{1}{(2\pi)^{\frac{n}{2}}|\Sigma|^{\frac{1}{2}}} \exp\left(a'P'\mu - \frac{1}{2}\mu'D\mu\right) d\mu$$

second change of variables

$$x = \left(\frac{D}{2}\right)^{\frac{1}{2}}\mu - \left(\frac{D}{2}\right)^{\frac{-1}{2}}\frac{Pa}{2}$$

$$\text{then } x'x = \frac{1}{2}\mu'D\mu - a'P'\mu + \frac{1}{2}a'P'D^{-1}Pa$$

$$\text{we then have } E_t exp(a'\nu) = \int \frac{1}{(2\pi)^{\frac{n}{2}}|\Sigma|^{\frac{1}{2}}} \exp\left(-x'x + \frac{a'\Sigma a}{2}\right)|\frac{D}{2}|^{\frac{-1}{2}} dx$$

$$E_t exp(a'\nu) = \exp\left(\frac{a'\Sigma a}{2}\right) = \exp(\frac{\sigma^2}{2}var(\epsilon^c) + \sigma cov(\epsilon^c, \epsilon^\pi) + \frac{1}{2}var(\epsilon^\pi))$$

Then I can rewrite

$$E_t\left(\frac{U_c(t+1)}{U_c(t)}\frac{1}{\Pi_{t+1}}\right) = E_t(exp(a'y_{t+1})) = exp\left(a'E_t(y_{t+1})\right) exp\left(\frac{a'\Sigma a}{2}\right) \tag{12}$$

In logarithm, this expression is a linear combination of economic variables including the second moments of the errors. Moreover, when the utility function is CES with habit formation under a multiplicative form as in Abel (1990), this result can be easily generalized.

Although it avoids a first order approximation, this method still forms a strong assumption: second moments Σ are constant. In particular, this assumption shuts down one channel for precautionary savings: when the environment is more uncertain, Σ increases, which is equivalent to a decrease in the interest rate. This channel of uncertainty shocks could account for an important share of business cycle fluctuations (Bloom, 2009).

C Confirming Canzoneri et al. (2007) on French data

If the Euler equation holds and households are rational and forming their expectations through a VAR model, the following should hold under log-normality hypothesis (Appendix B):

$$i_t = \sigma E_t \Delta c_{t+1} + E_t \pi_{t+1} - ln(\beta) - \left(\frac{\sigma^2}{2} var(\epsilon^c) + \sigma cov(\epsilon^c, \epsilon^\pi) + \frac{1}{2} var(\epsilon^\pi) \right) \quad (13)$$

with $E_t \Delta c_{t+1}$, $E_t \pi_{t+1}$ the expectations formed through a VAR model for consumption growth and inflation respectively and ϵ^c, ϵ^π the errors of this VAR model.

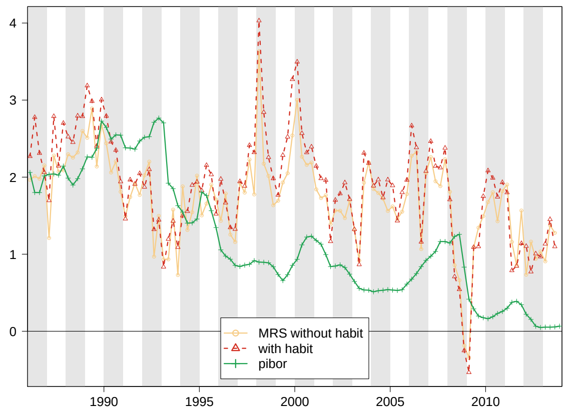
Considering external habit formation or catching-up with the Joneses under a multiplicative form Abel (1990); Gali (1994) modifies the preceding system by adding the lagged value of Δc_t in the Euler equation whose coefficient will depend on both σ and the habit formation parameter γ. The theoretical link (13) between expected consumption and interest rate becomes:

$$i_t = \sigma E_t \Delta c_{t+1} - \gamma(1-\sigma)\Delta c_t + E_t \pi_{t+1} - ln(\beta) - \left(\frac{\sigma^2}{2} var(\epsilon^c) + \sigma cov(\epsilon^c, \epsilon^\pi) + \frac{1}{2} var(\epsilon^\pi) \right) \quad (14)$$

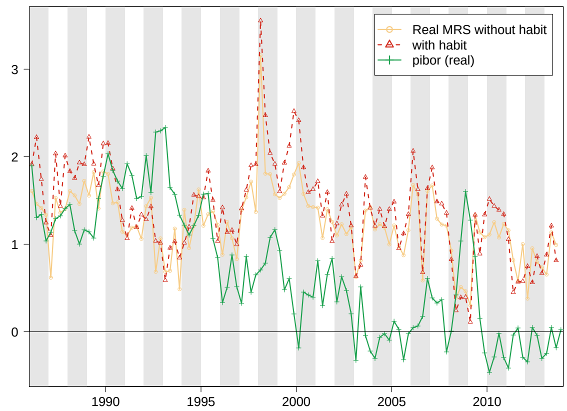
with households' utility a CES function of $\frac{C_t}{C_{t-1}^{\gamma}}$.

It is possible to assess graphically the fit to the Euler equation as in Canzoneri et al. (2007) by assuming a value for σ, γ and plotting actual interest rates with the marginal rate of substitution between present and future consumption, either in real or nominal terms.

Figures 4 depict such comparisons using consumption in non-durables, with and without habit formation. These figures exhibit similar features to the US case reproduced in Figure 5. First, these graphs show that adding *habit formation in the utility function* does not move the *MRS* closer to the actual monetary policy rate. Tables 6 display some statistics for both countries. On average, there are positive spreads between the *MRS* implied by Euler equations and the monetary policy rate. As Canzoneri et al. point out, these spreads "have been well documented in the literature on the equity premium puzzle and the risk free rate puzzle" and are not a strong argument against the Euler equation. However the correlations reported in these tables are weak, even though their sign is not clear cut and depend on the way actual nominal rates are converted in real terms. These correlations are outlined by Canzoneri et al. as a *challenge* for macroeconomists and in particular for monetary policy models.



(a) nominal



(b) real

Figure 4: Pibor and *MRS* with a CES utility function ($\sigma = 2$) with and without habit formation ($\gamma = 0.6$)

	Fedfunds	CES	CES with habit
Mean	0.44	1.89	1.61
Std deviation	0.7	0.75	0.51
Minimum	-0.95	-0.39	0.11
Maximum	2.82	3.65	2.71
Correlation1	1	0.09	0.1
Correlation2	1	-0.01	-0.01

(a) US

	Pibor	CES with habit	CES
Mean	0.71	1.24	1.4
Std deviation	0.73	0.41	0.54
Minimum	-0.46	0.3	0.11
Maximum	2.33	3.16	3.55
Correlation1	1	0.15	0.16
Correlation2	1	0.07	0.1

(b) France

I test two transformations of actual nominal rates in real terms: correlation 1 corresponds to the rate deflated with contemporaneous inflation $i_t - \pi_t$ and correlation 2 uses expected future inflation $i_t - E_t\pi_{t+1}$.

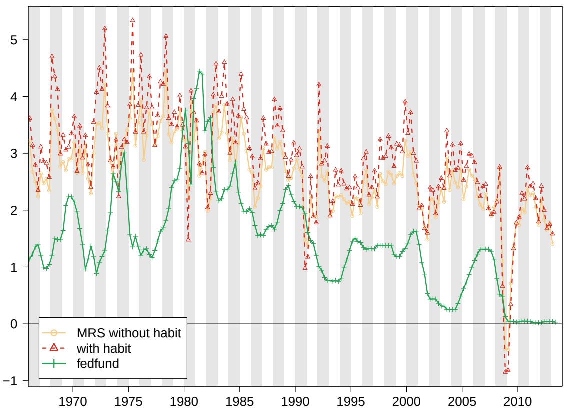
Table 6: Statistics for the actual and *MRS* (in real terms)

Figure 5 confirms Canzoneri et al.'s qualitative results for the US: the *MRS* markedly departs from the monetary policy rate "*during the Volcker tightening in the early 1980s*" and "*during the Greenspan easing in the early 2000s*". In addition in the mid 1990s, the *MRS* levelled off while actual rate remained stable. Also, in 2008 consumption nose dived more drastically than the interest rate would have implied: in nominal terms both rates plummeted, but in real terms *MRS* dropped while the real monetary policy rate peaked.

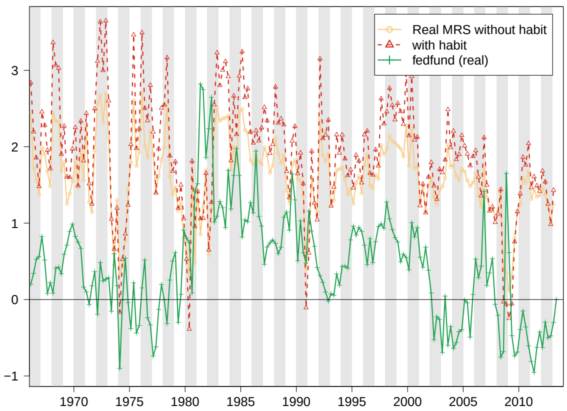
Figure 4 shows similar mismatch for France: the *MRS* mirrored the monetary policy rate in the 1990s and 2000s. In 2008, the French rates show the same disconnection in real and nominal terms as in the US.

Robustness to the calibration and the definition of the consumption bundle

Canzoneri et al. (2007) show that their results are robust to the definition of the utility function (with and without habit formation, either internal or external, additive or multiplicative) they also consider recursive utility and liquidity constraints (Campbell and Mankiw, 1990). As another robustness test, I compute similar *MRS* using other definitions of the consumption bundle and other calibrations of the utility function. Additional results are depicted on Figures 6 with



(a) nominal



(b) real

Figure 5: US Fedfund and *MRS* with a CES utility function ($\sigma = 2$) with and without habit formation ($\gamma = 0.6$)

a CES utility function without habit formation. These figures show, for three standard values of the intertemporal elasticity of substitution (2, 1, 0.5), the *MRS* computed with the VARX of expectations using four definitions of the consumption bundle (total consumption, consumption excluding durables, excluding energy or excluding committed expenditures (Quinet and Ferrari, 2008)). These interest rates are compared with the 3 month interbank rate and four different household specific rates, deposits and loans with various maturities (see section 1). Comparisons are made both in real and nominal terms. Tables 7 display the correlation matrices of the actual and *MRS* in real terms.

Figure 6a, 6c and 6e show that in nominal terms, the *MRS* from the Euler equations does not greatly depend on the consumption bundle considered, at least not in a way which would solve Canzoneri et al.'s challenge. Also they are more volatile than actual interest rates, all the more so when σ is large.

In real terms, deflated by actual inflation, the larger volatility of the *MRS* is not clear cut (figure 6b, 6d and especially 6f). However, there remains a sizeable discrepancy between the levels of the *MRS* and interest rates set by the market in the eighties up to the mid-nineties. This stylized fact has often been interpreted in France in line with the liberalisation of financial markets over these years.

For each calibration, the interest rates can be split in two groups based on the correlations (Tables 7): *MRS* and actual interest rates. Even though the correlations between these groups can be sizeable (up to 50% for the *livret*), the correlations within these groups are much larger and often close to one. These results are in line with Canzoneri et al.'s conclusions.

In addition to testing several definitions of consumption, I tested 3 VAR models to measure households expectations: one in first difference with two lags, one with additional regressors

(σ = 0.5)

Euler eq. rate total consumption	1	-	-	-	-	-	-	-
cons. excl. energy	0.86	1	-	-	-	-	-	-
cons. excl. durables	0.94	0.78	1	-	-	-	-	-
cons. excl. committed exp.	0.94	0.83	0.86	1	-	-	-	-
Pibor	0.22	-0.03	0.28	0.19	1	-	-	-
Deposit1y	0.22	-0.05	0.29	0.18	0.99	1	-	-
Livret	0.5	0.07	0.53	0.47	0.62	0.64	1	-
Mortgage	0.27	0.01	0.36	0.21	0.94	0.96	0.66	1

(σ = 1)

Euler eq. rate total consumption	1	-	-	-	-	-	-	-
cons. excl. energy	0.87	1	-	-	-	-	-	-
cons. excl. durables	0.93	0.78	1	-	-	-	-	-
cons. excl. committed exp.	0.94	0.87	0.84	1	-	-	-	-
Pibor	0.17	-0.06	0.27	0.13	1	-	-	-
Deposit1y	0.16	-0.08	0.26	0.12	0.99	1	-	-
Livret	0.31	-0.06	0.37	0.31	0.62	0.64	1	-
Mortgage	0.21	-0.02	0.34	0.15	0.94	0.96	0.66	1

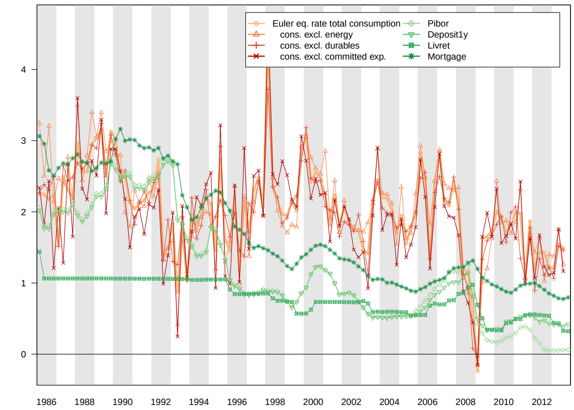
(σ = 2)

Euler eq. rate total consumption	1	-	-	-	-	-	-	-
cons. excl. energy	0.89	1	-	-	-	-	-	-
cons. excl. durables	0.92	0.78	1	-	-	-	-	-
cons. excl. committed exp.	0.92	0.9	0.8	1	-	-	-	-
Pibor	0.13	-0.07	0.24	0.08	1	-	-	-
Deposit1y	0.11	-0.1	0.23	0.06	0.99	1	-	-
Livret	0.16	-0.14	0.22	0.18	0.62	0.64	1	-
Mortgage	0.16	-0.04	0.3	0.1	0.94	0.96	0.66	1

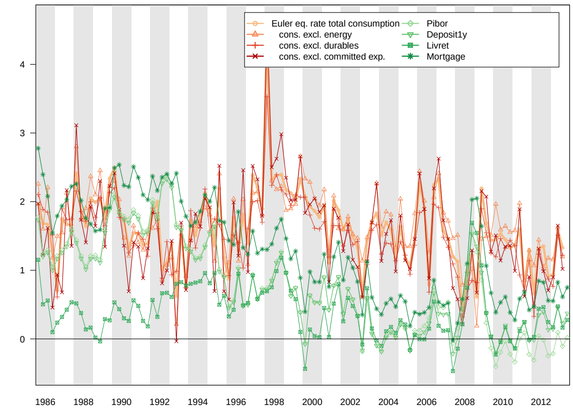
Table 7: Correlation matrix of Euler equation and actual interest rates in real terms

identical to those in the benchmark models of this paper, one in over the year growth rate with the same regressors and households survey data.[6] The present results are robust to these changes in the VAR model.

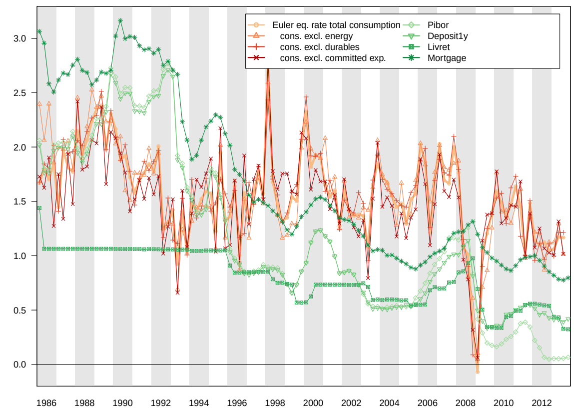
[6]Balances of opinion on households survey data match the evolution of macroeconomic data over the year, in particular gross disposable income, better than over the quarter.



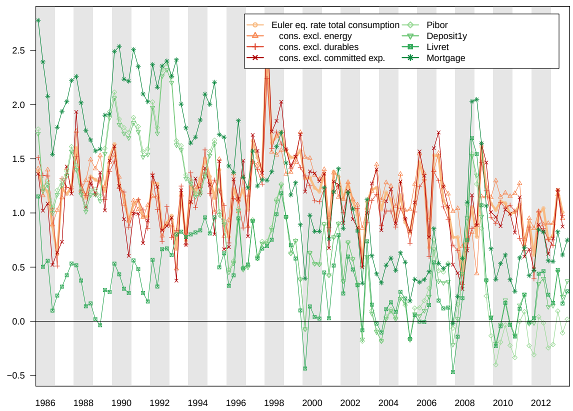
(a) $\sigma = 2$, nominal



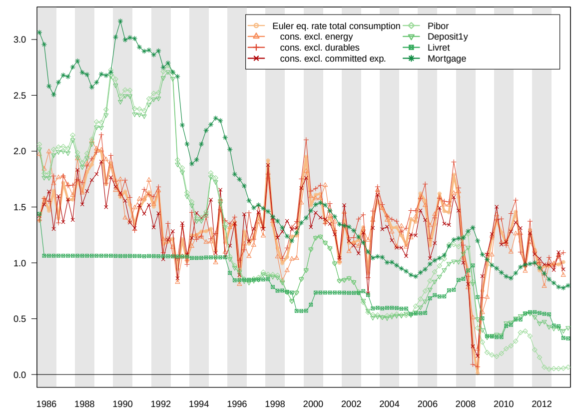
(b) $\sigma = 2$, real



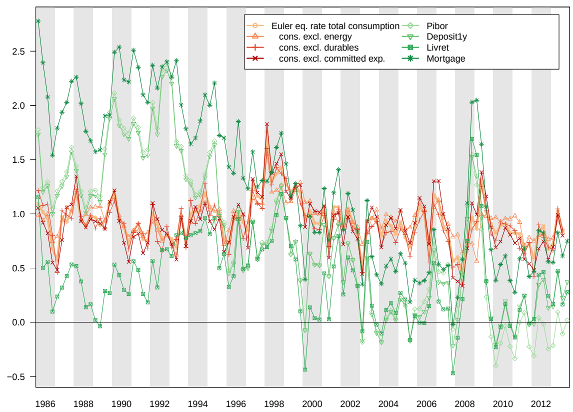
(c) $\sigma = 1$, nominal



(d) $\sigma = 1$, real



(e) $\sigma = 0.5$, nominal



(f) $\sigma = 0.5$, real

Figure 6: (FR) Actual interest rates and *MRS* for 4 definitions of the consumption bundle with a CES utility function without habit formation

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