Liquidity Risk and Investor Behavior: Issues, Data and Models

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1 Motivation

Investment funds and liquidity risk exposure

- **Hedge funds** perform liquidity transformation and provide different liquidity conditions to investors (mismatch between assets and liabilities)
- But **daily mutual funds** are also exposed to this liquidity transformation risk, especially when investors are active
- This liquidity transformation risk is related to :
  - the average assets liquidity exposure - *market liquidity risk*
  - the clients' liquidity consumption - *funding liquidity risk*

Previous studies

- Previous empirical studies have shown that both market **and** funding liquidity are priced in the cross-section of fund's returns

Market : SADKA 2006-2010, TEO 2011

Funding : DUDLEY & NIMALENDRAN 2010 ARAGON & STRAHAN 2012

Both : AGARWAL, ARAGON & SHI 2015

- They mostly use regression evidence using market and funding liquidity indicators on the right-hand side
- HOMBERT & THESMAR 2014 first paper to **endogenize the funding liquidity exposure** via constraints on withdrawals

Our paper - *Understanding investor behavior*

- We study the link between the investor behavior and the liquidity risk exposure of an investment fund
- Using a new set of proprietary data on individual investors orders, we can split net flows observed **at the fund level**
- We use Self-Exciting and Mutual-Exciting processes to model flows' persistence and forecast future flows **at the investor level**
- We then use these forecasts to predict the future evolution of the fund's asset under management

Research questions

- Question 1 : Do investors adjust their (liquidity) behavior depending on the funds liquidity exposure ?
- Question 2 : Do we observe lead/lag effects in the behavior of different types of investors ?
- Question 3 : Does investor behavior impact the calculation of a Liquidity-adjusted *Value-at-Risk* ?

Related business issues

- Issue 1 : Design new information systems with **data** at the investor level - *IT departments*
- Issue 2 : Develop portfolio allocation and risk **models** incorporating time-varying AUM - *Research departments*
- Issue 3 : New risk **metrics** to monitor liquidity risk - *Risk departments*

2 First example

Darolles, Roussellet (2016), *Hedge Fund Portfolio Management with Illiquid Assets*, consider a funds living for 2 periods which has access to two assets :

- **Cash :** zero interest rate, available every period
- **Illiquid asset :** fixed rate of return $\rho_1 + \rho_2$, available at period $t = 2$ only

The simplified fund balance-sheet is :

Assets	Liabilities
Cash Illiquid asset	AUM

Timing

$t = 0$ $\rightarrow$ The fund chooses a portfolio composition $(\delta, 1 - \delta)$ in cash/illiquid asset

$t = 1$ $\rightarrow$ With probability π, a fraction θ of AUM is withdrawn by the investors

- $\theta \sim \mathcal{U}[0, \bar{\theta}]$, where $\bar{\theta} \leqslant 1$
- If $\theta \leqslant \delta$, the fund takes its cash to pay the investors
- If $\theta > \delta$, the fund has to sell the illiquid asset on a secondary market

$t = 2$ $\rightarrow$ The final value of the fund's portfolio is realized

Funding liquidity shock θ associated with parameters π and $\bar{\theta}$

Liquidation cost on the secondary market

The illiquid asset has a known return $\rho_1 + \rho_2$ at period $t = 2$

- ρ_1 alone would be the friction-less return at period $t = 1$

Market liquidity shock

The realized return of the illiquid asset on the secondary market is equal to $\rho_1 - T$, where T is the market liquidity shock

- $T \sim \mathcal{E}(\lambda)$, where $\lambda > 0$
- λ is an indicator of market liquidity, $1/\lambda$ is the average rebate on the secondary market

When does default arise ?

Two situations can arise when a "big" θ is observed :

- The realized return $\rho_1 - T$ is sufficiently high to cover the discrepancy $\theta - \delta$. I sell a proportion γ of the illiquid asset equal to :

$$\boxed{\gamma(1-\delta)\exp(\rho_1 - T) = \theta - \delta \Longleftrightarrow \gamma = \frac{\theta - \delta}{1-\delta}\exp(T - \rho_1)}$$

- If T is too high, selling all the illiquid asset is not sufficient to cover $\theta - \delta$. The default is triggered whenever :

$$\boxed{(1-\delta)\exp(\rho_1 - T) < \theta - \delta \Longleftrightarrow \gamma > 1}$$

Default probability with exogenous cash

- With the assumptions made on liquidity shocks, it is possible to obtain the conditional distribution of γ given a liquidity shock
- The unconditional default probability is a by-product :

Default probability

$$\mathbb{P}(\gamma > 1) = \frac{\pi(\overline{\theta} - \delta)^{\lambda+1}}{\overline{\theta}(\lambda + 1)(1 - \delta)^{\lambda}} e^{-\lambda \rho_1}$$

- This probability is decreasing in the market liquidity λ, increasing in the size of the maximal possible funding shock $\overline{\theta}$ and decreasing in the cash amount δ

Endogenous cash management

Optimal cash amount (*when* $\theta = 1$ *- no gate*)

$$\delta^*(\lambda, \pi, \rho_1, \rho_2) = \frac{G(\lambda, \rho_1) + H_1(\pi, \rho_1, \rho_2)}{G(\lambda, \rho_1) + H_2(\rho_1, \rho_2)}$$

- δ^* is a function of λ (*market liquidity*) through $G(\cdot)$ only
- δ^* is a function of π (*funding liquidity*) through $H_1(\cdot)$ only

The main assumption to get this result is :

Funding liquidity shock

The value of θ is the funding liquidity shock. It is associated with parameters π and $\overline{\theta}$.

And with a more realistic assumptions on the investor behavior ?

Data on individual investor behavior can help to find the good set of assumptions

3 Data

- The context - A collaborative project between
  - 3 French asset management companies
  - A consultancy firm specialized in clients services
  - An IT firm
  - An academic research team
- The project started two years ago
- The database does not exist yet - only non structured data at each AM company level
- The main task is to design a data format and create the database

- Size
  - Today : several hundreds of funds
  - Tomorrow : several thousands of funds
- Limitations
  - Today : we observe trades within each companies
  - Tomorrow : no limitation
- Approaches
  - Today : at each funds level
  - Tomorrow : at the industry level

Descriptive statistics (1/3)

Firm	Fonds	Category	# Shares	Inception	AUM
AM 1			**16**		**4 292 294 936**
	Funds 1	Euro Equity Large Cap	3	02/10/1998	329 723 439
	Funds 2	Euro Equity Mid/Small Cap	2	06/09/1991	376 326 122
	Funds 3	Euro Fixed Income	2	03/07/1992	255 141 000
	Funds 4	Euro Fixed Income	3	24/02/1982	375 685 999
	Funds 5	Euro Fixed Income	3	05/02/1990	935 044 376
	Funds 6	Euro Money Market	2	31/12/1985	450 074 000
	Funds 7	Euro Money Market	1	07/07/1995	1 570 300 000
AM 2			**19**		**4 384 532 001**
	Funds 8	Euro Equity Large Cap	5	20/11/2001	280 424 002
	Funds 9	Euro Equity Mid/Small Cap	5	11/05/1994	333 368 999
	Funds 10	Euro Fixed Income	5	25/10/2000	354 900 000
	Funds 11	Euro Money Market	4	08/03/2006	3 415 839 000
AM 3			**8**		**2 037 509 155**
	Fonds 12	Euro Money Market	2	01/04/2013	1 319 876 994
	Fonds 13	Euro Equity Large Cap	3	09/01/2001	295 271 161
	Fonds 14	Euro Equity Mid/Small Cap	2	14/02/1997	34 287 000
	Fonds 15	Euro Money Market	1	30/11/2001	388 074 000
Total			**42**		**10 714 366 092**

Descriptive statistics (2/3)

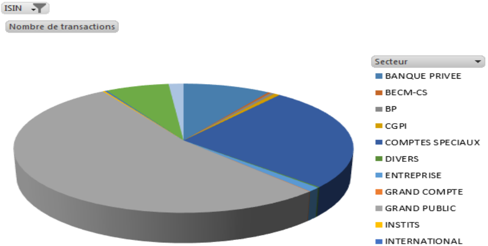
	C	D	E	F	G	H	I	J	K	L	M	N	O
1	Secteur	Sous-secteur	Statut	Client Anonymisé	Quantité	Montant net	Date cours	Devise opé.	Stock	Statut	ISIN	Cours	Sens
2	Mutuelle d'A	INSC - Insura	Mandat OFI	Client OFI 964	-1 500,00	-162 945,00	13/01/15	EUR	0	Provisoire ap	FR00009798	108,63	
3	Mutuelle d'A	INSC - Insura	Mandat OFI	Client OFI 718	6 300,00	684 369,00	09/01/15	EUR	34300	Valorisé	FR00009798	108,63	
4	Family Office	OFIN - Other	Client	Client OFI 870	9 259,00	1 005 712,58	05/01/15	EUR	9259	Valorisé	FR00009798	108,62	
5	OPCVM Grou	OPCVM Grou	OPC OFI	Client OFI 802	-189 000,00	-20 525 400,(	29/12/14	EUR	0	Valorisé	FR00009798	108,6	
6	Association /	OFIN - Other	Mandat OFI	Client OFI 834	-4 200,00	-456 162,00	24/12/14	EUR	0	Valorisé	FR00009798	108,61	
7	Mutuelle d'A	INSC - Insura	Mandat OFI	Client OFI 845	-6 400,00	-695 104,00	24/12/14	EUR	0	Valorisé	FR00009798	108,61	
8	Mutuelle d'A	INSC - Insura	Mandat OFI	Client OFI 845	6 400,00	695 104,00	24/12/14	EUR	6400	Valorisé	FR00009798	108,61	
9	Association /	OFIN - Other	Mandat OFI	Client OFI 834	4 200,00	456 162,00	24/12/14	EUR	4200	Valorisé	FR00009798	108,61	
10	CIBTP	INSC - Insura	Client	Client OFI 195	-921	-100 020,60	23/12/14	EUR	6491,9	Valorisé	FR00009798	108,6	
11	Mutuelle d'A	INSC - Insura	Mandat OFI	Client OFI 648	-7 500,00	-814 500,00	23/12/14	EUR	0	Valorisé	FR00009798	108,6	
12	Family Office	OFIN - Other	Client	Client OFI 870	-18 708,00	-2 031 688,8	23/12/14	EUR	0	Valorisé	FR00009798	108,6	
13	Mutuelle d'A	INSC - Insura	Mandat OFI	Client OFI 648	7 000,00	760 200,00	23/12/14	EUR	7000	Valorisé	FR00009798	108,6	
14		Others	OPC OFI	Client OFI 508	6 355,00	690 089,45	22/12/14	EUR	6355	Valorisé	FR00009798	108,59	
15	Mutuelle d'A	INSC - Insura	Mandat OFI	Client OFI 889	1 400,00	152 026,00	22/12/14	EUR	3400	Valorisé	FR00009798	108,59	
16	CIBTP	INSC - Insura	Client	Client OFI 195	-3 685,00	-400 080,45	19/12/14	EUR	7412,9	Valorisé	FR00009798	108,57	
17	OPCVM Grou	OPCVM Grou	Client	Client OFI 372	-19 822,88	-2 151 178,5	17/12/14	EUR	-19822,877	Valorisé	FR00009798	108,52	
18	Mutuelle d'A	INSC - Insura	Mandat OFI	Client OFI 111	-10 330,00	-1 121 011,6	17/12/14	EUR	0	Valorisé	FR00009798	108,52	
19	OPCVM Grou	OPCVM Grou	Client	Client OFI 372	19 822,88	2 151 178,56	17/12/14	EUR	0	Valorisé	FR00009798	108,52	
20	Mutuelle d'A	INSC - Insura	Mandat OFI	Client OFI 718	-10 000,00	-1 085 100,0	16/12/14	EUR	28000	Valorisé	FR00009798	108,51	
21	IRP	PFND - Pensi	Client	Client OFI 963	-92 378,75	-10 026 789,;	15/12/14	EUR	0	Valorisé	FR00009798	108,54	
22	Mutuelle d'A	INSC - Insura	Mandat OFI	Client OFI 692	10 000,00	1 085 400,00	15/12/14	EUR	19250	Valorisé	FR00009798	108,54	
23	Mutuelle d'A	INSC - Insura	Mandat OFI	Client OFI 964	-1 000,00	-108 620,00	08/12/14	EUR	6000	Valorisé	FR00009798	108,62	
24	Mutuelle d'A	INSC - Insura	Mandat OFI	Client OFI 490	4 600,00	499 652,00	08/12/14	EUR	21000	Valorisé	FR00009798	108,62	
25	Mutuelle d'A	INSC - Insura	Mandat OFI	Client OFI 648	-2 500,00	-271 500,00	04/12/14	EUR	7500	Valorisé	FR00009798	108,6	
26	CIBTP	INSC - Insura	Client	Client OFI 283	42 000,00	4 561 200,00	04/12/14	EUR	292200	Valorisé	FR00009798	108,6	
27	Mutuelle d'A	INSC - Insura	Mandat OFI	Client OFI 964	-1 000,00	-108 610,00	26/11/14	EUR	7000	Valorisé	FR00009798	108,61	
28	Plateforme	NONE - No ir	Client	Client OFI 54	-1	-108,61	25/11/14	EUR	0	Valorisé	FR00009798	108,61	
29	Mutuelle d'A	INSC - Insura	Mandat OFI	Client OFI 964	-1 000,00	-108 610,00	25/11/14	EUR	8000	Valorisé	FR00009798	108,61	
30	CIBTP	INSC - Insura	Client	Client OFI 276	9 207,26	1 000 000,00	25/11/14	EUR	9207,2553	Valorisé	FR00009798	108,61	
31	Mutuelle d'A	INSC - Insura	Mandat OFI	Client OFI 673	11 000,00	1 194 710,00	25/11/14	EUR	11000	Valorisé	FR00009798	108,61	
32	Mutuelle d'A	INSC - Insura	Mandat OFI	Client OFI 501	-21 850,00	-2 372 473,0	19/11/14	EUR	0	Valorisé	FR00009798	108,58	
33	Entreprises	NFCO - Non-l	Client	Client OFI 444	73 500,00	7 982 100,00	18/11/14	EUR	73500	Valorisé	FR00009798	108,6	
34	Compagnie c	INSC - Insura	Client	Client OFI 570	36 822,00	3 998 869,20	18/11/14	EUR	36822	Valorisé	FR00009798	108,6	
35	Mutuelle d'A	INSC - Insura	Mandat OFI	Client OFI 718	-5 000,00	-543 050,00	17/11/14	EUR	38000	Valorisé	FR00009798	108,61	

Descriptive statistics (3/3)

Funds	Period	# Days	Number			Freq (in days)		
			Inflows	*Outflows*	*trades*	*Inflows*	*Outflows*	*trades*
AM 1			**522 015**	**283 034**	**805 049**			
Funds 1	2013-14	497	174 903	22 134	197 037	351,91	44,53	396,44
Funds 2	2013-14	497	144 992	20 880	165 872	297,73	42,01	399,74
Funds 3	2013-14	497	18 942	6 436	25 378	38,11	12,95	51,06
Funds 4	2013-14	497	3 709	5 983	9 692	7,46	12,04	19,50
Funds 5	2013-14	497	5 671	7 323	12 994	11,41	14,73	26,14
Funds 6	2013-14	497	36 779	54 044	90 823	74	108,74	182,74
Funds 7	2013-14	497	137 019	166 234	303 253	275,69	334,47	610,37
AM 2			**52 773**	**68 955**	**121 728**			
Fonds 8	2010-14	1252	7 005	6 354	13 359	5,60	10,67	16,27
Fonds 9	2010-14	1252	5 663	4037	9 700	4,52	7,75	12,27
Fonds 10	2010-14	1252	1 399	6 952	8 351	1,12	6,67	7,79
Fonds 11	2010-14	1252	38 706	51 612	90 318	30,92	72,14	103,05
AM 3			**4 119**	**5 299**	**9 418**			
Fonds 12	2013-14	493	210	312	522	0,43	0,63	1,06
Fonds 13	2010-14	1 249	1 468	1 400	2 868	1,18	1,12	2,3
Fonds 14	2010-14	1 115	1 877	3 023	4 900	1,68	2,71	4,39
Fonds 15	2010-14	1 233	564	564	1 128	0,46	0,46	0,91
Total			**578 907**	**357 288**	**936 195**			

Flows by Investors type

ISIN	(Plusieurs éléments)
Typologies	**Nombre de transactions**
BANQUE PRIVEE	917
BECM-CS	29
BP	44
CGPI	62
COMPTES SPECIAUX	2559
DIVERS	17
ENTREPRISE	106
GRAND COMPTE	6
GRAND PUBLIC	5210
INSTITS	21
INTERNATIONAL	22
PLATEFORME BQ	669
SDG	156
Total général	**9818**

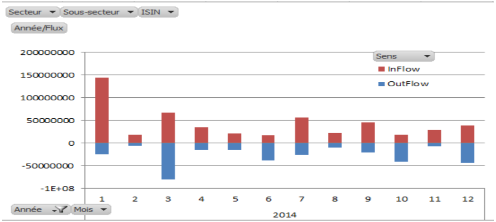


- What is the best classification ?
- Do we observe a different behavior by type ?

1. At the monthly inflow and outflow level

We can disentangle in- and outflows from net flows

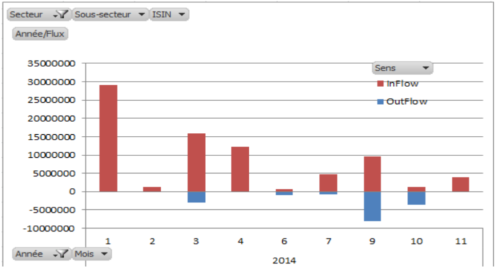
Secteur	(Tous)		
Sous-secteur	(Tous)		
ISIN	(Tous)		
Année/Flux	Flow		
Mois	OutFlow	InFlow	NetFlow
2014	**-328700847,3**	**513425116,7**	**184724269,3**
1	-24726353,72	144556851,8	119830498,1
2	-5630282,42	18032710,1	12402427,68
3	-80736321,86	67354412,57	-13381909,29
4	-15170602,45	34321809,48	19151207,03
5	-15460185,51	21770528,88	6310343,37
6	-37769565,19	16589432,99	-21180132,2
7	-26184373,84	56611316,3	30426942,46
8	-9668516,67	21977191,57	12308674,9
9	-20838975,99	45134827,69	24295851,7
10	-40785431,35	19138840,92	-21646590,43
11	-7534171,5	29261331,44	21727159,94
12	-44196066,84	38675862,93	-5520203,91
NetFlow	**-328700847,3**	**513425116,7**	**184724269,3**



2. For an investors type

All "Insurance" clients in 2014

Secteur	Compagnie d'Assurance		
Sous-secteur	(Tous)		
ISIN	(Tous)		
Année/Flux	Flow		
Mois	OutFlow	InFlow	NetFlow
2014	-16334097	78647581,66	62313484,66
1		29129300	29129300
2		1291780	1291780
3	-2907840	15917768,5	13009928,5
4	-215620	12160371,46	11944751,46
6	-898226	757050	-141176
7	-800976	4675764,5	3874788,5
9	-8006562	9523068	1516506
10	-3504873	1193610	-2311263
11		3998869,2	3998869,2
NetFlow	-16334097	78647581,66	62313484,66

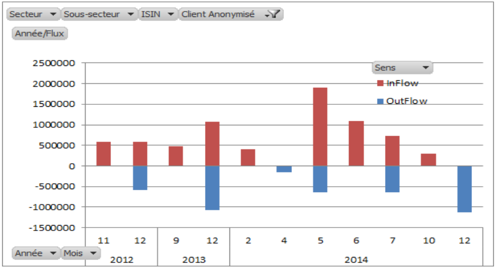


3. For a single investor

Client 111 history on the last 3 years

Secteur	(Tous)
Sous-secteur	(Tous)
ISIN	(Tous)
Client Anonymisé	Client OFI 111

Année/Flux	Flow		
Mois	OutFlow	InFlow	NetFlow
2012			
11		590072	590072
12	-592144	592144	0
2013			
9		470228	470228
12	-1073800	1073800	0
2014			
2		397898	397898
4	-147713,4		-147713,4
5	-647880	1905280	1257400
6		1082100	1082100
7	-649440	722100	72660
10		304014	304014
12	-1121011,6		-1121011,6
NetFlow	-4231989	7137636	2905647



4 First empirical results

We start with a simple *(static)* model to fit the data :

- The natural choice is a Poisson distribution

We extend this first model step by step :

- by adding parameters to capture observed stylized facts
- by evaluating the model quality with standard criteria (Mean Square Error, AIC ...)

For presentation purpose, we first use only one (very liquid) funds to compare the different specifications. Only the last model is estimated on 4 funds with different liquidity levels

1D Homogenous Poisson Model (with over-dispersion)

$$N_t = \mathcal{P}(\lambda F_t) = \mathbb{P}(\lambda, \gamma)$$

- N_t : aggregated trades (inflows and outflows)
- λ : intensity of Poisson distribution
- $F_t > 0$ with $E(F_t) = 1$: latent factor introduced to create over-dispersion - *negative binomial distribution (parameter γ)*

Model	λ	γ
1D (H)	54.46***	21.45***

With our dataset, we can then treat separately inflows and outflows in a two-dimensional model

2D Homogenous Poisson Model

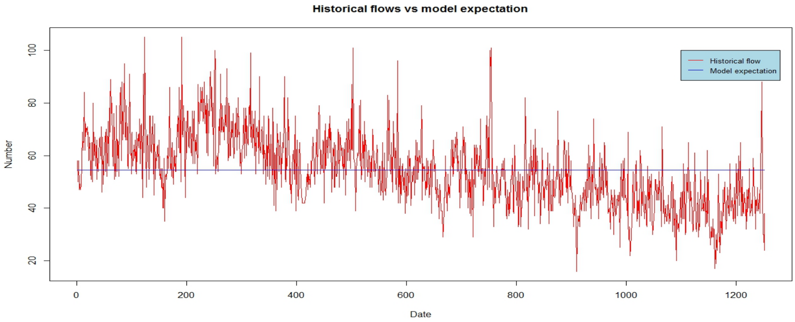
$$N_t^{in} = \mathbb{P}(\lambda^{in}, \gamma^{in})$$
$$N_t^{out} = \mathbb{P}(\lambda^{out}, \gamma^{out})$$

Model	λ^{in}	λ^{out}	γ^{in}	γ^{out}
2D (H)	25.13***	29.32***	17.48***	22.61***

But very bad predictors ....

Model prediction : 2D (H) - *inflows*

We compute the 1-day predicted value (*blue line*) and compare it to the realized value (*red line*)



We observe both persistence and clustering effects on flow series. **Only a dynamic model can capture these effects**

2D Self-Exciting Model

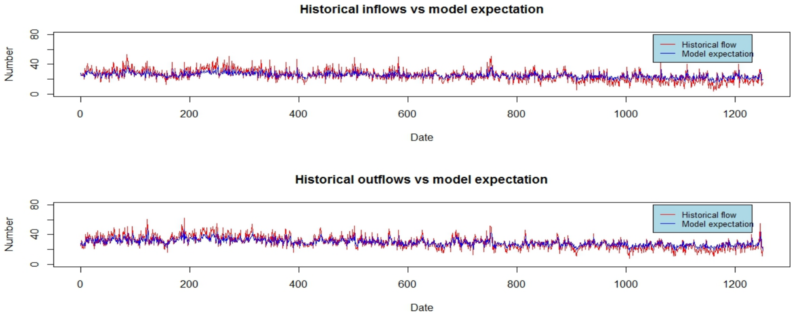
$$\lambda_t^{in} = \lambda_0^{in} + \rho^{in} N_t^{in}$$
$$\lambda_t^{out} = \lambda_0^{out} + \rho^{out} N_t^{out}$$

- $\lambda_0^{in/out}$: a constant term (base intensity)
- $\rho^{in/out}$: the correlation term (the previous flow will "update" the next intensity)

Model	λ^{in}	λ^{out}	ρ^{in}	ρ^{out}	γ^{in}	γ^{out}
2D (SE)	13.42***	12.75***	0.46***	0.56***	17.48***	22.61***

Model prediction : 2D (SE)

We compute the 1-day predicted value (*blue line*) and compare it to the realized value (*red line*)



The persistence effects of flows can be completed by adding cross effects between inflows and outflows

2D Mutual-Exciting Model

$$\lambda_t^{in} = \lambda_0^{in} + \rho^{in-in} N_t^{in} + \rho^{in-out} N_t^{in}$$
$$\lambda_t^{out} = \lambda_0^{out} + \rho^{out-in} N_t^{in} + \rho^{out-out} N_t^{out}$$

- $\rho^{\cdots}$: The impact of previous flows to next intensity
- e.g. ρ^{in-out} : correlation of the inflow intensity to the previous outflow
- e.g. $\rho^{out-out}$: correlation of the outflow intensity to the previous outflow
- Other parameters in the model are as same as previous model

What "Self/Mutual Exciting" means ?

- "Self Exciting"

	Previous Inflow	Previous Outflow
Inflow	reputation	
Outflow		financial runs/ panic

- "Mutual Exciting"

	Previous Inflow	Previous Outflow
Inflow	reputation	commercial ability
Outflow	smart money	financial runs/ panic

Empirical results

TABLE : Estimators

Model	λ^{in}	λ^{out}	In-In	In-Out	Out-In	Out-Out	γ^{in}	γ^{out}
1D (H)	54.46***						21.45***	
2D (H)	25.13***	29.32***					17.48***	22.61***
2D (SE)	13.42***	12.75***	0.46***			0.56***	17.49***	22.62***
2D (ME)	8.15***	10.84***	0.32***	0.30***	0.19***	0.46***	35.56***	44.94***

Empirical results

TABLE : Model quality

Model	Param.	MSE-In	MSE-Out	MSE-All	AIC
1D (Homo)	2			239903.1	
2D (Homo)	4	74821.25	84638.42	159459.7	-315870.4
2D (SE)	6	60588.69	59129.57	119718.3	-316328.2
2D (ME)	8	55940.79	57183.28	113124.1	-316478.2

4 funds (different categories)

TABLE : Model estimation

Category	λ^{in}	λ^{out}	In-In	In-Out	Out-In	Out-Out	γ^{in}	γ^{out}
MoneyMarket	8.1***	10.1***	**0.32*** **	**0.30*** **	**0.19*** **	**0.46*** **	35.5***	44.9***
EqtyLarCap	4.3***	4.8*	**0.22*** **	0.00	**0.78*** **	**0.18*** **	35.9***	68.8***
EqtySmallCap	0.5***	1.1***	**0.52*** **	**0.06** **	**0.16*** **	**0.19*** **	2.5***	4.4***
FixedIncome	0.4***	0.4***	**0.10* **	0.00	0.00	0.02	0.5***	0.7***

Research question 1 : **YES** - Investors adjust their (liquidity) behavior depending on the funds liquidity exposure

Contagion : dependence between clients types

Objectives :

1. Empirical evidences of contagion between types
2. Analyze the risk when the liability composition is time varying

2 sectors :

- Insurance (AS) & "Social protection group" (PS)
- Linked activities
- Significant flows (AS 13 537 & PS 11 031)

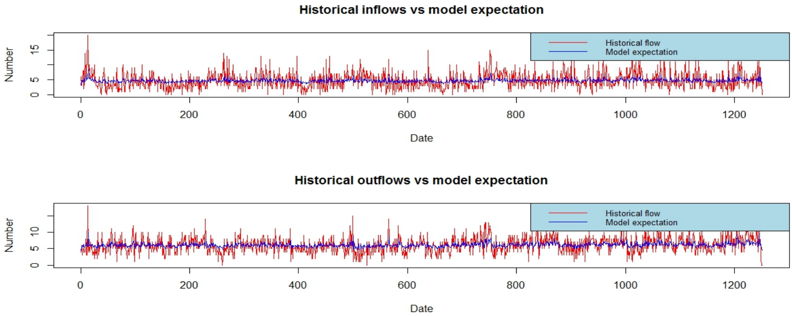
2 x 2D (ME) model

We first estimate two 2D (ME) model for comparison purpose

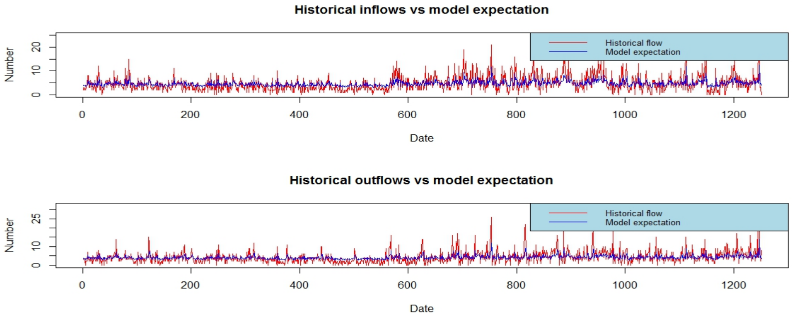
TABLE : 2D (ME) Model estimation for two types

Model	λ^{in}	λ^{out}	In-In	In-Out	Out-In	**Out-Out**	γ^{in}	γ^{out}
AS-2D (ME)	3.25***	4.26***	0.19***	0.08*	0.05*	**0.25*** **	7.76***	36.63***
PS-2D (ME)	2.86***	2.54***	0.31***	0.08**	0.08**	**0.29*** **	6.47***	4.93***

Model quality : 2D (ME) for AS

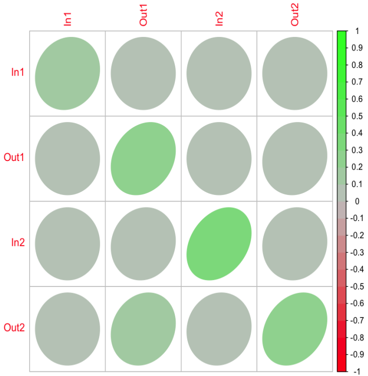


Model quality : 2D (ME) for PS



4D model (Contagion)

Contagion matrix



Estimators

	Estimate	Std. Error	z value	Pr(z)	
Base_in1	3.931456	0.272512	14.4267	< 2.2e-16	***
Base_out1	4.115734	0.291452	14.1215	< 2.2e-16	***
Base_in2	2.275925	0.267991	8.4926	< 2.2e-16	***
Base_out2	1.632884	0.260640	6.2649	3.730e-10	***
In1_In1	0.116882	0.029549	3.9555	7.638e-05	***
In1_Out1	0.001000	0.031909	0.0313	0.974999	
In1_In2	0.034625	0.025437	1.3612	0.173461	
In1_Out2	0.019175	0.025261	0.7591	0.447799	
Out1_In1	0.032231	0.029968	1.0755	0.282154	
Out1_Out1	0.227773	0.034969	6.5136	7.338e-11	***
Out1_In2	0.018554	0.027638	0.6713	0.502014	
Out1_Out2	0.087299	0.028015	3.1162	0.001832	**
In2_In1	0.030685	0.027705	1.1076	0.268046	
In2_Out1	0.091277	0.032438	2.8139	0.004895	**
In2_In2	0.300877	0.029389	10.2377	< 2.2e-16	***
In2_Out2	0.066998	0.028191	2.3766	0.017473	*
Out2_In1	0.017244	0.027520	0.6266	0.530915	
Out2_Out1	0.161549	0.033942	4.7595	1.940e-06	***
Out2_In2	0.074917	0.027268	2.7475	0.006005	**
Out2_Out2	0.267678	0.032503	8.2356	< 2.2e-16	***
Gamma_In1	10.641801	1.582141	6.7262	1.741e-11	***
Gamma_Out1	22.707555	2.417837	9.3917	< 2.2e-16	***
Gamma_In2	7.521537	0.858245	8.7639	< 2.2e-16	***
Gamma_Out2	5.136202	0.450970	11.3892	< 2.2e-16	***

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

-2 log L: -30979.89

Research question 2 : YES - we observe lead/lag effects between different types of investors

Empirical results - 2 types

TABLE : Model quality

Model	N	MSE-In	MSE-Out	MSE-All
AS 2D (ME)	8	9297.692	7031.586	**16329.28**
AS 4D (ME)	12	9291.72	7005.21	**16296.93**
PS 2D (ME)	8	10867.42	11407.5	**22274.92**
PS 4D (ME)	12	10819.93	11168.1	**21988.03**

5 Conclusion and next developments

Research questions

- Question 1 : **YES** - Investors adjust their (liquidity) behavior depending on the funds liquidity exposure
- Question 2 : **YES** - we observe lead/lag effects between different types of investors
- Question 3 : **YES** - Investor behavior impacts the calculation of a Liquidity-adjusted *Value-at-Risk*

- First steps in the modeling of individual investor behavior
- Inflows and outflows must be considered separately
- Clients types are also important to consider
- Measure contagion at the industry level (and not just at the funds level)
- Start to to do big data things !