## Parallel VTFR

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### Scenario Analysis and Experiment Design

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- Scenarios for Probabilities of Dismissal

### Next Steps

## Team HPCFal

- Teamlead: Riccardo Gismondi
- Researchers:
  - Kujtim Avdiu
  - Bernhard Bruckner
  - Christian Kremnitzer
  - Peter Kreuzinger
  - Johannes Menzel
- start in June 2007

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#### Our Team

## **Our Projects**

- PVTFR (Parallelized Valutazione Trattamento Fine Rapporto) to be presented at OR 2008 in Augsburg, September 2008
- Application of Parallel Genetic Algorithms for the Calibration of Financial Models (FIRM presentation in June 2008)
- Model Risk and Calibration Risk
- Just-In-Time Implied Volatility Estimation of Stock Options applying Parallel Computing
- Asset Liability Management, Stochastic Optimization and Parallel Computing
- Optimal Trading Strategies through Genetic Programming
- Parallel SPES (Standard Pricing Estimator System)

today, we will provide an insight into PVTFR

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## An Introduction to VTFR

- VTFR: Valutazione Trattamento Fine Rapporto
- target of VTFR:
  - to calculate a robust estimation of future pension liability for a dedicated company for all its employees
  - in Italy, as well as in other European countries it is a legal obligation (see IAS 19)

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## Input Values of VTFR

- interest rate
- inflation rate
- basic salary growth rate
- salary growth rate dependent on employee qualification level
- death probabilities
- probabilities of invalidity
- probabilities of dismissal
- hypothesis for payments in advance
- we have to deal with a great number of input factors
- input factors are stochastic
- we do not know the joint distribution of the input factors
- $\Rightarrow$  Monte Carlo Approach

## Monte Carlo Approach in VTFR

- employees stay in a company and the pension liabilities increase, until an employee
  - dies,
  - becomes invalid,
  - leaves the company (dismissal) or
  - retires
- we estimate the pension liabilities by
  - generating a huge number of employee's life paths
  - estimate future pension liabilities
  - discount future liabilities to current time
    - => taking the average gives us the MC estimator

## Specification of Input Parameters

slutazione TFR Test firm-19092007	
	dpendenti: 20
Tasso di Inflazione (p.e.: 2,0)	o di incremento delle retribuzioni (p.e.: 3.0) 3 e di cariera: Personalizza
Ipotesi Demografiche Probabilità di Morte: Robabilità di Inhibita: Orano di dimissioni Oranoni di dimissioni Personalizza	lpotesi di pensionamento:minima intermeda massima
Ipotesi richiesta anticipazioni No. massimo di anticipi (p.e.: 1) <u>1</u> Probabilita di anticipizioni (p.e.: 3,0) <u>3</u>	Percentuale anticipazione (p.e.: 70,0) 70 Anni minimi tra 2 anticip (p.e.: 99,0) 99
Ipotesi calcolo Numero smulazioni (p.e.: 1000) ⊙ automatico ◯ manuale	Data di valutazione (dd/mm/yyyy): Informazione per riconciliazione
	Reset lpotesi Salva lpotesi Baborazione Indetro

### Figure: Specification of Input Parameters

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## Specification of Input Parameters II

	Personalizzazione Probabilitza di Dunitssioni					
	Mi	aschi I	Femmine	Masc	hi Fernmine	Dimissioni per
	1	0,01	0.025	26 0,	01 0,025	Servizio
		0,01	0.025	27 0		
		0,01	0.025	28 0,	01 0,025	
		0,01	0,025	29 0,		
	5	0,01	0,025	30 0,	01 0,025	
	6	0,01	0,025	31 0,	01 0,025	
	7	0,01	0,025	32 0,	01 0,025	
o di Rendimento Atteso 🗙	8	0,01	0,025	33 0,	01 0,025	
	9	0,01	0,025	34 0,	01 0,025	
Inserisci valore Tasso (p.e. 4.0)	10	0,01	0,025	35 0,	01 0,025	
_ Interior ratio (p.e. 4/o)	11	0,01	0,025	36 0,	01 0,025	
	12	0,01	0,025	37 0,	01 0,025	
Inserisci valore Indice IBOXX (p.e. 4.0)	13	0,01	0,025	38 0,	01 0,025	
Difference and a procession of the state of	14	0,01	0,025	39 0,	01 0,025	
	15	0,01	0,025	40 0,	01 0,025	
	16	0,01	0,025	41 0,	01 0,025	
✓ Inserisci vettore SWAP (p.e. 4.0 - in ogni campo)	17	0,01	0,025	42 0,	01 0,025	
a manual rectare show gues its integrit canges)	18	0,01	0,025	43 0,	01 0,025	
Swap 1 anno: 1 Swap 6 anni: 3 Swap 12 anni: 6	19	0,01	0,025	44 0,	01 0,025	
Swap 2 anni: 2 Swap 7 anni: 4 Swap 15 anni: 7	20	0,01	0,025	45 0,	01 0,025	
Swap 3 anni: 2 Swap 8 anni: 4 Swap 20 anni: 8		0,01	0,025	46 0,	01 0,025	
Swap 4 anni: 3 Swap 9 anni: 5 Swap 25 anni: 9	22	0,01	0,025	47 0,	01 0,025	
Swap 5 anni: 3 Swap 10 anni: 5 Swap 30 anni: 10	23	0,01	0,025	48 0,	01 0,025	
	24	0,01	0,025	49 0,	01 0,025	
	25	0,01	0,025	50 0,	01 0,025	
Ronistina lipotesi Salvato Reset (potesi Salva lipotesi Indetto	Valore ( (p.e.: 0	da replicar 3,01)		Applica Applica	a femmine Repli	ca Ipotesi
			Ripristina ipo	tesi salvate	Reset Ipotesi Si	alva Ipotesi Indietro

Figure: Specifying Interest Rate and Probability of Dismissal

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## Results

Data acquisizione informazioni:							
lumero dipendenti:	12.799						
		Smonta	nento TFR: Smontamento	Elminati	Anno	Smontamento	Elminati
ast Service Liability (inizio periodo)	1	1	48.387.753,14	835,81	26	686.630,1	108,82
assivita in bilancio (inizio periodo)	0	2	36.711.347,95	706,27	27	475.213,96	100,37
iervice Cost	0	3	45.685.053,59	908,19	28	435.410,09	99,7
nterest Cost	0	4	43.919.447,7	943,86	29	338.153,76	95,75
meresi cosi mortization (Gain) / Loss	1	5	36.357.514,16	816,46	30	247.837,56	77,19
Inrecognized (Gain) / Loss	0	6	34.329.115,89	778,29	31	235.270,71	80,17
ictuarial (Gain) / Loss	362,528,511.04	7	28.869.887,93	690,83	32	149.242,71	54,27
'ransfer in / (out)	1	8	23.552.662,18	579,27	33	50.322,6	13,24
utilizzi)	1	9	25.149.260,51	651,4	34	18.033,95	8,85
rasferimenti a Fondo Pensione e altro	1	10	20.744.717,16	534,92	35	12.247,68	5,35
ast Service Liability (fine periodo)	362.528.516.84	11	20.101.933,14	546,89	36	8.270,51	3,13
Inrecognized Actuarial (Gain) / Loss	362,528,511,64	12	13.853.517,54	404,78	37	437,1	1,04
assivita in bilancio (fine periodo)	725.057.028.68	13	10.335.764,32	309,44	38	1.061,71	1,95
ermanenza Media Residua	7.61	14	8.388.879,5	274,83	39	0	0
ermanenza media residua		15	9.744.055,42	319,77	40	0	0
asso di rendimento utilizzato:		16	11.981.136,35	400,62	41	0	0
		17	10.590.308,59	373,54	42	0	0
tisultato per matricola:		18	7.660.006,84	301,17	43	0	0
1908 - PSL:	54.201,79	19	7.677.780,29	319,03	44	0	0
1908 A TER:	55,275,2	20	8.500.156,02	362,26	45	0	0
2186		21	6.344.024,13	299,02	46	0	0
2258 Saldo:	1.073,41	22	3.824.667,08	237,4	47	0	0
2315		23	2.668.945,27	207,59	48	0	0
2344 (in sec.): 2445	4,3	24	2.107.002,31	189,88	49	0	0
2454 •		25	1.398.165,45	157,57	50	0	0
				Salva screer	rshot	Salva file excel	Grafico

## Figure: Results of VTFR Estimation

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## VTFR technology

### JAVA

- primarily the implementation was based on JAVA, since
  - JAVA is fast, platform independent and today the de facto standard in programming

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- computing intensive applications were sourced out to C, since
  - C is machine oriented and
  - especially for huge companies that have lots of employees, the computational time can be reduced substantially
  - using JNI (JAVA Native Interface)
  - this is where the Cluster@WU and PVTFR comes in

## What factors mostly affect the results?

- question:
  - What are the factors that most influence the results of VTFR?
- answer:
  - Interest Rate
  - Inflation Rate
  - Probabilities of Dismissal
- also the death probabilities are time variant
- the population more and more grows older
- i.e. e.g. a 30-year old man in 2008 has generally a higher death probability than a 30-year old in 2010
- dynamic death tables considering future death probabilites are included

## What factors mostly affect the results?

- include scenario analysis for the 3 risk factors
- this enables a more robust estimation of future pension liabilities
- we have to care about the restrictions of the Cluster@WU
  - since we still have 68  $\times$  2 = 136 processors, we can not run as much scenarios as we want in a reasonable time

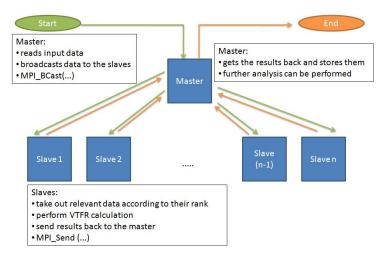
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• consequently, we have to apply adequate sampling techniques

## Sketch of Program Sequence



### Figure: Sketch of Program Sequence

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## Short Explanation of Program Sequence

- currently, the application uses a 21 node framework (1 master + 20 slaves)
- the number of scenarios is equivalently shared between the slaves
- e.g. 100 scenarios  $\div$  20 slaves = 5 scenarios per node
- the VTFR calculation lies completely on the slaves
- no communication between the slaves necessary
- each slave returns its results to the master
- the master bundles the results into one array and saves the results to the output file
- further analysis can be performed

## Running VTFR in an MPI Environment

- an excerpt of our mpi.job file:
  - #\$ -N vtfr #\$ -pe lam 21 #\$ -q node.q

```
mpirun -t -np 21 ./mm -t -pdata parameters.txt -cdata company.txt -sdata scenariodata.txt -e 12799 -s 100
```

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lamtrace -mpi trace.ltr

## Running and Debugging an MPI Task

- debugging parallel applications is a very challenching task
- visualization can help you
- XMPI-http://www.lam-mpi.org/software/xmpi/
- bar chart:
  - RED: blocked, waiting on communication
  - YELLOW: time spent inside an MPI function
  - GREEN: node is running
- additional analyse tools:
  - pie charts
  - traffic lights

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## Graphical Debugging Tools

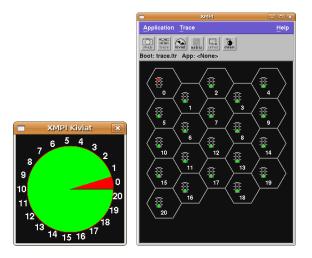
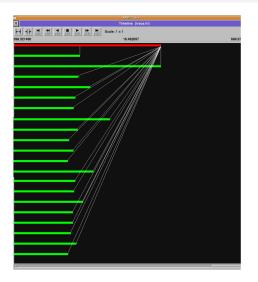


Figure: Pie Charts and Traffic Lights can be very helpful



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## Visualized Program Sequence observed with MPI Trace



### Figure: PVTFR Program Sequence

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- given a company (Italian bank) with 12.799 employees
- and let us assume that our cluster offers approximately 100 free nodes

	Computational_Time@Cluster@WU
1 simulation within	0.03 sec.
a single scenario	
10.000 simulations necessary	10.000 * 0.03 sec.
for robust estimations	= 300  sec. = 5  min.

### we started out with

100 scenarios for	interest rate
100 scenarios for	inflation
100 scenarios for	probabilities of dismissal

• this leads to a computational time of

100 scenarios  $\times$  5 min. per scenario / 100 nodes = 5 min.

- there is no problem running the interest-, inflation-, dismissal-scenarios separately
- even when fewer nodes are in use (e.g. for 20 available nodes: 100 overall nodes / 20 nodes available × 5 min/scenario = 25 min)

- the combination of all the 100  $\times$  100  $\times$  100 = 10  $^{6}$  scenarios will be a serious problem
- theoretically:

 $\frac{10^{6} \text{ scenarios } \times 5 \text{ min/scenario } / 100 \text{ nodes} = 50.000 \text{ min} = 833,33 \text{ hours} = 34,72 \text{ days}}{50.000 \text{ min} = 833,33 \text{ hours} = 34,72 \text{ days}}$ 

- this is definitely too long
- coming from the other side and asking
  - "How long is the application allowed to run?" and
  - "How many scenarios can be performed within this time?"

- $\bullet\,$  the reduction of e.g. 60 % of the relevant scenarios will lead to
- 40  $\times$  40  $\times$  40 = 64  $\times$  10  $^3$  scenarios and this will take
- theoretically:

 $64 \times 10^3$  scenarios  $\times$  5 min/scenario / 100 nodes = 3.200 min = 53,33 hours = 2,22 days

- even not using all the nodes from the Cluster@WU, this will be a reasonable compromise
- onsequence:
  - provided that the underlying problem is designed badly, not even an expensive high performance computer can help you

## First Results of Estimation

starting with 100 basic scenarios

- inflation rate: 0.02
- interest rate: EUR SWAP
- probabilities of dismissal: observed data from customer
- number of simulations: 10000

Mean	3.47339229 ×10 <sup>8</sup>
Std. Deviation	$1.78273464 \times 10^{3}$
Skewness	-0.16631471
Kurtosis	3.52817135
Min.	3.47334258 ×10 <sup>8</sup>
Max.	$3.47344773 \times 10^{8}$

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## Interest Rate Scenarios

 $\bullet$  generate scenarios by applying a base point shift of  $\pm$  50 BP on the EUR SWAP curve

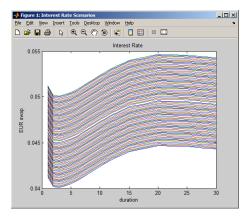


Figure: Generating Interest Rate Scenarios

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## Results for the Interest Rate Scenarios

### • scenario: Variant Interest Rate

- inflation rate: 0.02
- $\bullet\,$  interest rate: EUR SWAP  $\pm$  50 BP
- probabilities of dismissal: observed data from customer
- number of simulations: 10000

Mean	3.47216065 ×10 <sup>8</sup>
Std. Deviation	$6.34285683 \times 10^{6}$
Skewness	0.03457363
Kurtosis	1.78334055
Min.	3.36624497 ×10 <sup>8</sup>
Max.	$3.58166489 \times 10^8$
Max Min.	$21.541992 \times 10^{6}$

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## Impact of Scenario Implementation

• scenario P/L relative to the mean of our base scenario

### • best case:

absolute difference: 336.62 Mio - 347.34 Mio. = -10.72 Mio. relative difference: -3.08 %

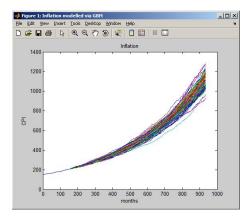
• worst case:

absolute difference: 358.17 Mio - 347.34 Mio. = +10.83 Mio. relative difference: +3.12 %

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## Inflation Scenarios

- base on historical CPI (Consumer Price Index) data
- modeling the inflation as Geometric Brownian Motion



### Figure: Inflation Scenarios

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#### Inflation Scenarios

## Results for the Inflation Scenarios

### scenario: Variant Inflation Rate

- inflation rate: modeled via Geometric Brownian Motion
- interest rate: EUR SWAP
- probabilities of dismissal: observed data from customer
- number of simulations: 10000

Mean	$3.56176609 \times 10^8$
Std. Deviation	$3.53186509 \times 10^{6}$
Skewness	-0.04253140
Kurtosis	2.47621072
Min.	$3.46543358 \times 10^8$
Max.	$3.63930861 \times 10^8$
Max Min.	$17.387503 \times 10^{6}$

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## Impact of Scenario Implementation

scenario P/L relative to the mean of our base scenario

• best case:

absolute difference: 346.54 Mio - 347.34 Mio. = -0.80 Mio. relative difference: -0.23 %

• worst case:

absolute difference: 358.17 Mio - 347.34 Mio. =+16.59 Mio. relative difference: +4.78 %

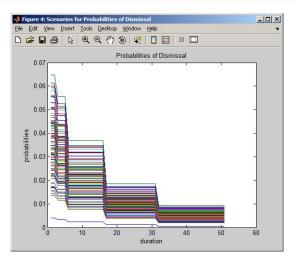
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## Scenarios for Probabilities of Dismissal

- based on observed data from our customer
- dependent on the number of years an employee is with the company, the probability of dismissal reaches from 3.5 to 0.5 %
- adding some noise N(0, 0.15) to the data generates our scenarios

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## Probabilities of Dismissal



### Figure: Scenarios for Probabilities of Dismissal

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## Basic and Extreme Scenarios

• just to point out the basic, lowest and highest scenario

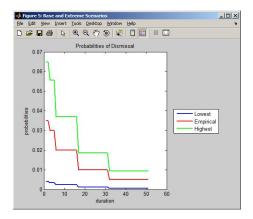


Figure: Showing the Extreme Scenarios Explicitly

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## Results for the Dismissal Scenarios

- scenario: Variant Probability of Dismissal
  - inflation rate: 0.02
  - interest rate: EUR SWAP
  - probabilities of dismissal: observed data + a noisy component N(0, 0.15)
  - number of simulations: 10000

Mean	3.46967848 ×10 <sup>8</sup>
Std. Deviation	$2.76540192 \times 10^{6}$
Skewness	-0.24027199
Kurtosis	3.08889392
Min.	$3.40099136 \times 10^8$
Max.	$3.54701025 \times 10^{8}$
Max Min.	$14.601889 \times 10^{6}$

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## Impact of Scenario Implementation

scenario P/L relative to the mean of our base scenario

### • best case:

absolute difference: 340.10 Mio - 347.34 Mio. = -7.24 Mio. relative difference: -2.08 %

• worst case:

absolute difference: 354.70 Mio - 347.34 Mio. = +7.36 Mio. relative difference: +2.12 %

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## Next steps

- combining scenarios
- applying adequate sampling techniques on multivariate stochastic processes
- combine sampled scenarios and
- perform a robust estimation of future pension liabilities

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# Thank you for your attention!

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