國立雲林科技大學
九十學年度研究所博士班入學考試試題

所別：管理研究所
科目：統計學

1.(10%) 令 $A=(i,j)$代表 2 個數字的一組資料，其中 i,j 皆爲自 0 到 9 的整數，且每組資料的 P(A)=0.01，試求 $Y=i+j$ 及 $Z=i-j$ 的機率分配。

2.(10%) 投擲一個骰子，一直到每面至少出現一次爲止，試求投擲次數的期望值。

3.(10%) 設檢定統計量 X 其樣本空間爲{ a,b,c,d,e }；欲檢定 $H_0: f_0(x)$ v.s $H_1: f_1(x)$，f_0與 f_1 皆爲機率函數，定義如下：

x	a	b	c	d	e
$f_0(x)$	0	0.1	0.2	0.3	0.4
$f_1(x)$	0.3	0	0.2	0.4	0.1

(1) 設拒絕域爲 { b,c }，求α與β
(2) 設拒絕域爲 { d }，求α與β
(3) 那一個拒絕域可獲得較佳的檢定？

4.(10%) 已知有下列資料，包括 4 組獨立隨機樣本的樣本數、平均數與標準差；試以 ANOVA 表檢定 $H_0: \mu_1=\mu_2=\mu_3=\mu_4$ ；$\alpha=0.05$

樣本組	樣本數	平均數	標準差
1	45	3.00	0.826
2	79	2.25	0.898
3	104	2.95	0.896
4	53	2.68	0.894

5.(10%) 利用最小平方法配適(fit)通過(0,0), (1,0), (2,2), (3,2)的二次迴歸方程式。

6.(10%) 自機率分配 $f(x;p)=q^{x-1}p, x=1,2,\cdots,$ 其中 $q=1-p$ ，抽出隨機樣本 2, 1, 2, 5, 2, 10, 5, 7, 9, 2, 1, 5；試求參數 p 的最大概似(maximum likelihood)估計值。

7.(10%) 聯合機率密度函數 $f(x,y)=e^{-x-y}, 0<x<\infty, 0<y<\infty$，
(1) 隨機變數 X 與 Y 是否獨立？ 請說明理由。
(2) 求機率 $\Pr(X>1, Y>1)$

8.(10%) 某亂數產生器(random number generator)其輸出的 500 個自 0 到 9 的整數之出現次數如下表，若是期望每一整數出現的機率皆相同，試以所提供之數據判斷此亂數產生器是否合乎要求。α=0.05

整數	0	1	2	3	4	5	6	7	8	9
次數	43	58	51	59	39	56	45	37	62	52

9.(10%) 某民調機構欲證明民眾支持總統處理經濟危機的態度之比例低於一半，若500位隨機樣本中，有228位表示支持
(1) 求檢定的p-值(p-value)。
(2). 若欲使民眾支持比例的誤差小於0.03的機率爲95%，需要多少樣本數？

10. (10%) 若有30筆(x,y)資料，其迴歸式爲 $y=\beta_0+\beta_1 x = 25+0.7x$ 且標準差 $S_x=2.4$, $S_y=3.0$，
(1) 求x,y的相關係數。
(2) 若 $\bar{x}=30$，求 $\bar{y}$ 值。
(3) 以ANOVA表檢定 H_0: $\beta_1=0$，$\alpha=0.05$

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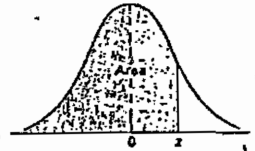

Table A.3 (continued) Areas Under the Normal Curve

z	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
0.0	0.5000	0.5040	0.5080	0.5120	0.5160	0.5199	0.5239	0.5279	0.5319	0.5359
0.1	0.5398	0.5438	0.5478	0.5517	0.5557	0.5596	0.5636	0.5675	0.5714	0.5753
0.2	0.5793	0.5832	0.5871	0.5910	0.5948	0.5987	0.6026	0.6064	0.6103	0.6141
0.3	0.6179	0.6217	0.6255	0.6293	0.6331	0.6368	0.6406	0.6443	0.6480	0.6517
0.4	0.6554	0.6591	0.6628	0.6664	0.6700	0.6736	0.6772	0.6808	0.6844	0.6879
0.5	0.6915	0.6950	0.6985	0.7019	0.7054	0.7088	0.7123	0.7157	0.7190	0.7224
0.6	0.7257	0.7291	0.7324	0.7357	0.7389	0.7422	0.7454	0.7486	0.7517	0.7549
0.7	0.7580	0.7611	0.7642	0.7673	0.7704	0.7734	0.7764	0.7794	0.7823	0.7852
0.8	0.7881	0.7910	0.7939	0.7967	0.7995	0.8023	0.8051	0.8078	0.8106	0.8133
0.9	0.8159	0.8186	0.8212	0.8238	0.8264	0.8289	0.8315	0.8340	0.8365	0.8389
1.0	0.8413	0.8438	0.8461	0.8485	0.8508	0.8531	0.8554	0.8577	0.8599	0.8621
1.1	0.8643	0.8665	0.8686	0.8708	0.8729	0.8749	0.8770	0.8790	0.8810	0.8830
1.2	0.8849	0.8869	0.8888	0.8907	0.8925	0.8944	0.8962	0.8980	0.8997	0.9015
1.3	0.9032	0.9049	0.9066	0.9082	0.9099	0.9115	0.9131	0.9147	0.9162	0.9177
1.4	0.9192	0.9207	0.9222	0.9236	0.9251	0.9265	0.9278	0.9292	0.9306	0.9319
1.5	0.9332	0.9345	0.9357	0.9370	0.9382	0.9394	0.9406	0.9418	0.9429	0.9441
1.6	0.9452	0.9463	0.9474	0.9484	0.9495	0.9505	0.9515	0.9525	0.9535	0.9545
1.7	0.9554	0.9564	0.9573	0.9582	0.9591	0.9599	0.9608	0.9616	0.9625	0.9633
1.8	0.9641	0.9649	0.9656	0.9664	0.9671	0.9678	0.9686	0.9693	0.9699	0.9706
1.9	0.9713	0.9719	0.9726	0.9732	0.9738	0.9744	0.9750	0.9756	0.9761	0.9767
2.0	0.9772	0.9778	0.9783	0.9788	0.9793	0.9798	0.9803	0.9808	0.9812	0.9817
2.1	0.9821	0.9826	0.9830	0.9834	0.9838	0.9842	0.9846	0.9850	0.9854	0.9857
2.2	0.9861	0.9864	0.9868	0.9871	0.9875	0.9878	0.9881	0.9884	0.9887	0.9890
2.3	0.9893	0.9896	0.9898	0.9901	0.9904	0.9906	0.9909	0.9911	0.9913	0.9916
2.4	0.9918	0.9920	0.9922	0.9925	0.9927	0.9929	0.9931	0.9932	0.9934	0.9936
2.5	0.9938	0.9940	0.9941	0.9943	0.9945	0.9946	0.9948	0.9949	0.9951	0.9952
2.6	0.9953	0.9955	0.9956	0.9957	0.9959	0.9960	0.9961	0.9962	0.9963	0.9964
2.7	0.9965	0.9966	0.9967	0.9968	0.9969	0.9970	0.9971	0.9972	0.9973	0.9974
2.8	0.9974	0.9975	0.9976	0.9977	0.9977	0.9978	0.9979	0.9979	0.9980	0.9981
2.9	0.9981	0.9982	0.9982	0.9983	0.9984	0.9984	0.9985	0.9985	0.9986	0.9986
3.0	0.9987	0.9987	0.9987	0.9988	0.9988	0.9989	0.9989	0.9989	0.9990	0.9990
3.1	0.9990	0.9991	0.9991	0.9991	0.9992	0.9992	0.9992	0.9992	0.9993	0.9993
3.2	0.9993	0.9993	0.9994	0.9994	0.9994	0.9994	0.9994	0.9995	0.9995	0.9995
3.3	0.9995	0.9995	0.9995	0.9996	0.9996	0.9996	0.9996	0.9996	0.9996	0.9997
3.4	0.9997	0.9997	0.9997	0.9997	0.9997	0.9997	0.9997	0.9997	0.9997	0.9998

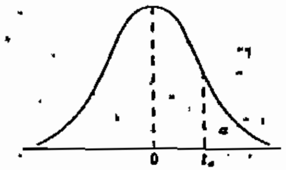

Table A.4 Critical Values of the t-Distribution

v	α						
	0.40	0.30	0.20	0.15	0.10	0.05	0.025
1	0.325	0.727	1.376	1.963	3.078	6.314	12.706
2	0.289	0.617	1.061	1.386	1.886	2.920	4.303
3	0.277	0.584	0.978	1.250	1.638	2.353	3.182
4	0.271	0.569	0.941	1.190	1.533	2.132	2.776
5	0.267	0.559	0.920	1.156	1.476	2.015	2.571
6	0.265	0.553	0.906	1.134	1.440	1.943	2.447
7	0.263	0.549	0.896	1.119	1.415	1.895	2.365
8	0.262	0.546	0.889	1.108	1.397	1.860	2.306
9	0.261	0.543	0.883	1.100	1.383	1.833	2.262
10	0.260	0.542	0.879	1.093	1.372	1.812	2.228
11	0.260	0.540	0.876	1.088	1.363	1.796	2.201
12	0.259	0.539	0.873	1.083	1.356	1.782	2.179
13	0.259	0.537	0.870	1.079	1.350	1.771	2.160
14	0.258	0.537	0.868	1.076	1.345	1.761	2.145
15	0.258	0.536	0.866	1.074	1.341	1.753	2.131
16	0.258	0.535	0.865	1.071	1.337	1.746	2.120
17	0.257	0.534	0.863	1.069	1.333	1.740	2.110
18	0.257	0.534	0.862	1.067	1.330	1.734	2.101
19	0.257	0.533	0.861	1.066	1.328	1.729	2.093
20	0.257	0.533	0.860	1.064	1.325	1.725	2.086
21	0.257	0.532	0.859	1.063	1.323	1.721	2.080
22	0.256	0.532	0.858	1.061	1.321	1.717	2.074
23	0.256	0.532	0.858	1.060	1.319	1.714	2.069
24	0.256	0.531	0.857	1.059	1.318	1.711	2.064
25	0.256	0.531	0.856	1.058	1.316	1.708	2.060
26	0.256	0.531	0.856	1.058	1.315	1.706	2.056
27	0.256	0.531	0.855	1.057	1.314	1.703	2.052
28	0.256	0.530	0.855	1.056	1.313	1.701	2.048
29	0.256	0.530	0.854	1.055	1.311	1.699	2.045
30	0.256	0.530	0.854	1.055	1.310	1.697	2.042
40	0.255	0.529	0.851	1.050	1.303	1.684	2.021
60	0.254	0.527	0.848	1.045	1.296	1.671	2.000
120	0.254	0.526	0.845	1.041	1.289	1.658	1.980
∞	0.253	0.524	0.842	1.036	1.282	1.645	1.960

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Table A.6* Critical Values of the F-Distribution

$f_{0.05}(v_1, v_2)$

v_2 \ v_1	1	2	3	4	5	6	7	8	9
1	161.4	199.5	215.7	224.6	230.2	234.0	236.8	238.9	240.5
2	18.51	19.00	19.16	19.25	19.30	19.33	19.35	19.37	19.38
3	10.13	9.55	9.28	9.12	9.01	8.94	8.89	8.85	8.81
4	7.71	6.94	6.59	6.39	6.26	6.16	6.09	6.04	6.00
5	6.61	5.79	5.41	5.19	5.05	4.95	4.88	4.82	4.77
6	5.99	5.14	4.76	4.53	4.39	4.28	4.21	4.15	4.10
7	5.59	4.74	4.35	4.12	3.97	3.87	3.79	3.73	3.68
8	5.32	4.46	4.07	3.84	3.69	3.58	3.50	3.44	3.39
9	5.12	4.26	3.86	3.63	3.48	3.37	3.29	3.23	3.18
10	4.96	4.10	3.71	3.48	3.33	3.22	3.14	3.07	3.02
11	4.84	3.98	3.59	3.36	3.20	3.09	3.01	2.95	2.90
12	4.75	3.89	3.49	3.26	3.11	3.00	2.91	2.85	2.80
13	4.67	3.81	3.41	3.18	3.03	2.92	2.83	2.77	2.71
14	4.60	3.74	3.34	3.11	2.96	2.85	2.76	2.70	2.65
15	4.54	3.68	3.29	3.06	2.90	2.79	2.71	2.64	2.59
16	4.49	3.63	3.24	3.01	2.85	2.74	2.66	2.59	2.54
17	4.45	3.59	3.20	2.96	2.81	2.70	2.61	2.55	2.49
18	4.41	3.55	3.16	2.93	2.77	2.66	2.58	2.51	2.46
19	4.38	3.52	3.13	2.90	2.74	2.63	2.54	2.48	2.42
20	4.35	3.49	3.10	2.87	2.71	2.60	2.51	2.45	2.39
21	4.32	3.47	3.07	2.84	2.68	2.57	2.49	2.42	2.37
22	4.30	3.44	3.05	2.82	2.66	2.55	2.46	2.40	2.34
23	4.28	3.42	3.03	2.80	2.64	2.53	2.44	2.37	2.32
24	4.26	3.40	3.01	2.78	2.62	2.51	2.42	2.36	2.30
25	4.24	3.39	2.99	2.76	2.60	2.49	2.40	2.34	2.28
26	4.23	3.37	2.98	2.74	2.59	2.47	2.39	2.32	2.27
27	4.21	3.35	2.96	2.73	2.57	2.46	2.37	2.31	2.25
28	4.20	3.34	2.95	2.71	2.56	2.45	2.36	2.29	2.24
29	4.18	3.33	2.93	2.70	2.55	2.43	2.35	2.28	2.22
30	4.17	3.32	2.92	2.69	2.53	2.42	2.33	2.27	2.21
40	4.08	3.23	2.84	2.61	2.45	2.34	2.25	2.18	2.12
60	4.00	3.15	2.76	2.53	2.37	2.25	2.17	2.10	2.04
120	3.92	3.07	2.68	2.45	2.29	2.17	2.09	2.02	1.96
∞	3.84	3.00	2.60	2.37	2.21	2.10	2.01	1.94	1.88

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Table A.6 (continued) Critical Values of the F-Distribution

$f_{0.05}(v_1, v_2)$

v_2 \ v_1	10	12	15	20	24	30	40	60	120	∞
1	241.9	243.9	245.9	248.0	249.1	250.1	251.1	252.2	253.3	254.3
2	19.40	19.41	19.43	19.45	19.45	19.46	19.47	19.48	19.49	19.50
3	8.79	8.74	8.70	8.66	8.64	8.62	8.59	8.57	8.55	8.53
4	5.96	5.91	5.86	5.80	5.77	5.75	5.72	5.69	5.66	5.63
5	4.74	4.68	4.62	4.56	4.53	4.50	4.46	4.43	4.40	4.36
6	4.06	4.00	3.94	3.87	3.84	3.81	3.77	3.74	3.70	3.67
7	3.64	3.57	3.51	3.44	3.41	3.38	3.34	3.30	3.27	3.23
8	3.35	3.28	3.22	3.15	3.12	3.08	3.04	3.01	2.97	2.93
9	3.14	3.07	3.01	2.94	2.90	2.86	2.83	2.79	2.75	2.71
10	2.98	2.91	2.85	2.77	2.74	2.70	2.66	2.62	2.58	2.54
11	2.85	2.79	2.72	2.65	2.61	2.57	2.53	2.49	2.45	2.40
12	2.75	2.69	2.62	2.54	2.51	2.47	2.43	2.38	2.34	2.30
13	2.67	2.60	2.53	2.46	2.42	2.38	2.34	2.30	2.25	2.21
14	2.60	2.53	2.46	2.39	2.35	2.31	2.27	2.22	2.18	2.13
15	2.54	2.48	2.40	2.33	2.29	2.25	2.20	2.16	2.11	2.07
16	2.49	2.42	2.35	2.28	2.24	2.19	2.15	2.11	2.06	2.01
17	2.45	2.38	2.31	2.23	2.19	2.15	2.10	2.06	2.01	1.96
18	2.41	2.34	2.27	2.19	2.15	2.11	2.06	2.02	1.97	1.92
19	2.38	2.31	2.23	2.16	2.11	2.07	2.03	1.98	1.93	1.88
20	2.35	2.28	2.20	2.12	2.08	2.04	1.99	1.95	1.90	1.84
21	2.32	2.25	2.18	2.10	2.05	2.01	1.96	1.92	1.87	1.81
22	2.30	2.23	2.15	2.07	2.03	1.98	1.94	1.89	1.84	1.78
23	2.27	2.20	2.13	2.05	2.01	1.96	1.91	1.86	1.81	1.76
24	2.25	2.18	2.11	2.03	1.98	1.94	1.89	1.84	1.79	1.73
25	2.24	2.16	2.09	2.01	1.96	1.92	1.87	1.82	1.77	1.71
26	2.22	2.15	2.07	1.99	1.95	1.90	1.85	1.80	1.75	1.69
27	2.20	2.13	2.06	1.97	1.93	1.88	1.84	1.79	1.73	1.67
28	2.19	2.12	2.04	1.96	1.91	1.87	1.82	1.77	1.71	1.65
29	2.18	2.10	2.03	1.94	1.90	1.85	1.81	1.75	1.70	1.64
30	2.16	2.09	2.01	1.93	1.89	1.84	1.79	1.74	1.68	1.62
40	2.08	2.00	1.92	1.84	1.79	1.74	1.69	1.64	1.58	1.51
60	1.99	1.92	1.84	1.75	1.70	1.65	1.59	1.53	1.47	1.39
120	1.91	1.83	1.75	1.66	1.61	1.55	1.50	1.43	1.35	1.25
∞	1.83	1.75	1.67	1.57	1.52	1.46	1.39	1.32	1.22	1.00

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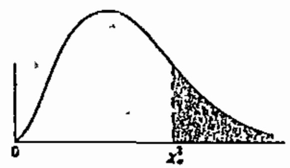

Table A.5 Critical Values of the Chi-Squared Distribution

v	α 0.995	0.99	0.98	0.975	0.95	0.90	0.80	0.75	0.75	0.50
1	0.0^4393	0.0^3157	0.0^3628	0.0^3982	0.00393	0.0158	0.0642	0.102	0.148	0.455
2	0.0100	0.0201	0.0404	0.0506	0.103	0.211	0.446	0.575	0.713	1.386
3	0.0717	0.115	0.185	0.216	0.352	0.584	1.005	1.213	1.424	2.366
4	0.207	0.297	0.429	0.484	0.711	1.064	1.649	1.923	2.195	3.357
5	0.412	0.554	0.752	0.831	1.145	1.610	2.343	2.675	3.000	4.351
6	0.676	0.872	1.134	1.237	1.635	2.204	3.070	3.455	3.828	5.348
7	0.989	1.239	1.564	1.690	2.167	2.833	3.822	4.255	4.671	6.346
8	1.344	1.646	2.032	2.180	2.733	3.490	4.594	5.071	5.527	7.344
9	1.735	2.088	2.532	2.700	3.325	4.168	5.380	5.899	6.393	8.343
10	2.156	2.558	3.059	3.247	3.940	4.865	6.179	6.737	7.267	9.342
11	2.603	3.053	3.609	3.816	4.575	5.578	6.989	7.584	8.148	10.341
12	3.074	3.571	4.178	4.404	5.226	6.304	7.807	8.438	9.034	11.340
13	3.565	4.107	4.765	5.009	5.892	7.042	8.634	9.299	9.926	12.340
14	4.075	4.660	5.368	5.629	6.571	7.790	9.467	10.165	10.821	13.339
15	4.601	5.229	5.985	6.262	7.261	8.547	10.307	11.036	11.721	14.339
16	5.142	5.812	6.614	6.908	7.962	9.312	11.152	11.912	12.624	15.338
17	5.697	6.408	7.255	7.564	8.672	10.085	12.002	12.792	13.531	16.338
18	6.265	7.015	7.906	8.231	9.390	10.865	12.857	13.675	14.440	17.338
19	6.844	7.633	8.567	8.907	10.117	11.651	13.716	14.562	15.352	18.338
20	7.434	8.260	9.237	9.591	10.851	12.443	14.578	15.452	16.266	19.337
21	8.034	8.897	9.915	10.283	11.591	13.240	15.445	16.344	17.182	20.337
22	8.643	9.542	10.600	10.982	12.338	14.041	16.314	17.240	18.101	21.337
23	9.260	10.196	11.293	11.688	13.091	14.848	17.187	18.137	19.021	22.337
24	9.886	10.856	11.992	12.401	13.848	15.659	18.062	19.037	19.943	23.337
25	10.520	11.524	12.697	13.120	14.611	16.473	18.940	19.939	20.867	24.337
26	11.160	12.198	13.409	13.844	15.379	17.292	19.820	20.843	21.792	25.336
27	11.808	12.879	14.125	14.573	16.151	18.114	20.703	21.749	22.719	26.336
28	12.461	13.565	14.847	15.308	16.928	18.939	21.588	22.657	23.647	27.336
29	13.121	14.256	15.574	16.047	17.708	19.768	22.475	23.567	24.577	28.336
30	13.787	14.953	16.306	16.791	18.493	20.599	23.364	24.478	25.508	29.336

Table A.5 (continued) Critical Values of the Chi-Squared Distribution

v	α 0.30	0.25	0.20	0.10	0.05	0.025	0.02	0.01	0.005	0.001
1	1.074	1.323	1.642	2.706	3.841	5.024	5.412	6.635	7.879	10.827
2	2.408	2.773	3.219	4.605	5.991	7.378	7.824	9.210	10.597	13.815
3	3.665	4.108	4.642	6.251	7.815	9.348	9.837	11.345	12.838	16.268
4	4.878	5.385	5.989	7.779	9.488	11.143	11.668	13.277	14.860	18.465
5	6.064	6.626	7.289	9.236	11.070	12.832	11.388	15.086	16.750	20.517
6	7.231	7.841	8.558	10.645	12.592	14.449	15.031	16.812	18.548	22.457
7	8.383	9.037	9.803	12.017	14.067	16.013	16.622	18.475	20.278	24.322
8	9.524	10.219	11.030	13.362	15.507	17.535	18.168	20.090	21.955	26.125
9	10.656	11.389	12.242	14.684	16.919	19.023	19.679	21.666	23.589	27.877
10	11.781	12.549	13.442	15.987	18.307	20.483	21.161	23.209	25.188	29.588
11	12.899	13.701	14.631	17.275	19.675	21.920	22.618	24.725	26.757	31.264
12	14.011	14.845	15.812	18.549	21.026	23.337	24.054	26.217	28.300	32.909
13	15.119	15.984	16.985	19.812	22.362	24.736	25.472	27.688	29.819	34.528
14	16.222	17.117	18.151	21.064	23.685	26.119	26.873	29.141	31.319	36.123
15	17.322	18.245	19.311	22.307	24.996	27.488	28.259	30.578	32.801	37.697
16	18.418	19.369	20.465	23.542	26.296	28.845	29.633	32.000	34.267	39.252
17	19.511	20.489	21.615	24.769	27.587	30.191	30.995	33.409	35.718	40.790
18	20.601	21.605	22.760	25.989	28.869	31.526	32.346	34.805	37.156	42.312
19	21.689	22.718	23.900	27.204	30.144	32.852	33.687	36.191	38.582	41.820
20	22.775	23.828	25.038	28.412	31.410	34.170	35.020	37.566	39.997	45.315
21	23.858	24.935	26.171	29.615	32.671	35.479	36.343	38.932	41.401	46.797
22	24.939	26.039	27.301	30.813	33.924	36.781	37.659	40.289	42.796	48.268
23	26.018	27.141	28.429	32.007	35.172	38.076	38.968	41.638	44.181	49.728
24	27.096	28.241	29.553	33.196	36.415	39.364	40.270	42.980	45.558	51.179
25	28.172	29.339	30.675	34.382	37.652	40.646	41.566	44.314	46.928	52.620
26	29.246	30.434	31.795	35.563	38.885	41.923	42.856	45.642	48.290	54.052
27	30.319	31.528	32.912	36.741	40.113	43.194	44.140	46.963	49.645	55.476
28	31.391	32.620	34.027	37.916	41.337	44.461	45.419	48.278	50.993	56.893
29	32.461	33.711	35.139	39.087	42.557	45.722	46.691	49.588	52.336	58.302
30	33.530	34.800	36.250	40.256	43.773	46.979	47.962	50.892	53.672	59.703

國立雲林科技大學
九十學年度研究所博士班入學考試試題

所別：管理研究所
科目：工業管理文獻

The following questions are based on the attached article entitled "Application of the multi-stage validation procedure in simulating a queuing system" by Chou, Liu and Chang (*Journal of Industrial Technology*, Vol. 12, No. 2, pp. 26-29, 1996). Please read through this article and answer the following questions.

1. (20%) In Table 2 on Page 27, the authors applied the Chi-square test procedure to determine the density function of the customers' interarrival time. Prior to use this procedure, one needs to make the null hypothesis. Suppose you have a set of data and you would like to apply the Chi-square test procedure to determine the appropriate density function for this set of data. How can you make your null hypothesis?

2. (20%) Suppose you would like to simulate the queuing system in a fast-food restaurant (e.g. McDonald's). Please describe the corresponding multi-stage validation procedure, including a possible purpose of the simulation, the required random variables to be tested by the Chi-square procedure (in the first stage), and the possible variables that you may use to validate the system (in the third stage).

3. (20%) Suppose you would like to simulate the queuing system in an intersection located in the urban area of Touliu (斗六). Please describe the corresponding multi-stage validation procedure, including a possible purpose of the simulation, the required random variables to be tested by the Chi-square procedure (in the first stage), and the possible variables that you may use to validate the system (in the third stage).

4. (20%) In Table 4 on Page 28, the actual value of the variable U1 (i.e. the utilization of serve 1) is not within its 95% confidence interval. Please give the possible reasons for this situation.

5. (20%) Please criticize this article based on your own opinions.

Application of the Multi-Stage Validation Procedure in Simulating a Queuing System

Dr. Chao-Yu Chou, Dr. Cheng-Hsin Liu, and Dr. Chun-Lang Chang

INTRODUCTION

Simulation is a powerful and valuable tool in the study of complex systems, e.g., transportation, manufacturing, service, and so forth. The applications of simulation on transportation systems may involve vehicle capacity design, planning and scheduling, highway design, traffic control system design and parking lot and structure design. In the world of manufacturing, simulation can be applied to study production planning, plant layout design, inventory control, assembly line balancing, materials handling and storage, and quality control. The popularity of simulation studies in manufacturing systems is rapidly increasing. Consequently, a considerable number of special purpose simulation tools are commercially available for manufacturing systems design and analysis. For the studies of service systems, simulation can be used in office system design, cash-flow analysis, distribution planning, and manpower planning and scheduling. In his book, Khoshnevis (1994) defines systems simulation as the practice of building models to represent existing real-world systems, or hypothetical future systems, and of experimenting with these models to explain system behavior, improve system performance, or design new systems with desirable performances. According to this definition, model building plays a very important role in systems simulation. A model is created for a specific purpose, and its adequacy or validity should be evaluated keeping the purpose in mind. If, in a series of rational and empirical tests of a model, large numbers of agreements are found with the real-world system, then our confidence on the model increases. Therefore, the validation process should use tests to see how well the model developed predicts the particular phenomenon under study. However, to determine whether a simulation model is an accurate representation of the actual system being studied, i.e., whether the model is valid, is always difficult. If a model is not valid, then any conclusions derived from the model will be of doubtful value (Law and Kelton, 1991).

In this paper, the method of multi-stage validation procedure (Naylor & Finger, 1967; Van Horn, 1971) will be reviewed and a case study of a particular queuing system will be given to illustrate how to carry out each step in the multi-stage validation procedure.

MULTI-STAGE VALIDATION PROCEDURE

The multi-stage validation procedure is a three-stage procedure. The first stage is to formulate a set of postulates of hypotheses from already acquired general knowledge of the system to be modeled, or from the knowledge of other similar systems that have already been modeled. The second stage is to validate these postulates empirically using appropriate statistical tests, if data are available. The third stage of the validation procedure is to investigate the degree to which the data generated by the model conform to the observed data.

The last stage of the validation procedure is very important and the final decision concerning the validity of the model must be based on it. If the model is to be used for descriptive analysis, the actual historical record produced by the system being modeled could be used to check the accuracy of predictions. There are a number of statistical techniques for testing the goodness of fit of a model, i.e., testing the degree of conformity of a simulated time series to the observed data. Some of them are the chi-square goodness-of-fit test (Hines & Montgomery, 1990), Kolmogorov-Smirnov test (Conover, 1980), and the inequality coefficient developed by Theil (Naylor, 1971). Theil inequality coefficient, denoted by U, provides an index which measures the degree to which a simulation model provides retrospective predictions of observed historical data. The value of U varies between zero and one. If $U = 0$, we have perfect predictions. If $U = 1$, we have very bad predictions.

A good example of validation procedure using Theil inequality coefficient was presented by Markland and Grandstaff (1974). They used a simulation approach to examine the public policy alternatives in the St. Louis metropolitan area. This model concentrated on the operation of the area labor market, and its primary objective was to provide a vehicle for public policy simulation experiments. First of all, they examined the regional economy of St. Louis area, and then constructed a simulation model. The last stage of the multi-stage validation procedure was applied to validate the simulation model; i.e., to test its reliability. In order to do this, it was proposed to initialize the model with values in 1960 for its variables, run it ten years, and then determine the extent to which the historical experience was reproduced by the model. When performing the statistical test, they used Theil inequality coefficient to indicate a perfect fit between predicted and actual values. Table 1 lists ten important variables of the model and some computed statistics. From Table 1, with the exception of the "migrants" variable, each of Theil inequality coefficients is close to zero. In addition, for the average percent error, none of the values departs very greatly from zero, except again for migration. This is probably because migration is the most volatile component of population change for a small-area economy. Emphasis of this example has been placed on the construction and validation of the model as necessary precedents to the actual simulation experimentation.

Table 1. Validation Statistics and Variables

variable	Theil inequality coefficient	average percent error	actual mean	predicted mean
population	0.006	1.1	2231.8	2244.9
births	0.020	3.1	45.9	46.9
net migrants	0.739	334.1	2.8	0.5
total employment	0.016	2.6	913.3	929.3
export employment	0.028	4.5	236.9	246.7
business employment	0.015	2.6	129.8	129.8
household employment	0.015	2.6	485.8	493.9
unemployment rate	0.090	10.9	4.4	4.2
wage index I	0.005	0.8	1.0164	1.0118
wage index II	0.005	0.7	1.1187	1.1104

Table 2. Chi-square Test Procedure for Customers' Interarrival Time

Value of AT	Probability	Expected No.	Observed No.
< 0.5	0.4092	81.84	70
0.5 - 1.0	0.2418	48.36	59
1.0 - 1.5	0.1428	28.56	36
1.5 - 2.0	0.0844	16.88	18
2.0 - 2.5	0.0498	9.96	7
2.5 - 3.0	0.0295	5.90	4
3.0 - 3.5	0.0174	3.48	4
3.5 - 4.0	0.0103	2.06	1
4.0 - 4.5	0.0060	1.20	0
4.5 - 5.0	0.0036	0.72	1
> 5.0	0.0052	1.04	0
Total	1.0000	200.00	200

CASE STUDY OF A QUEUING SYSTEM

In this section, the development of a simulation model for a queuing system in a post office will be discussed. The system operates eight hours per day; after eight hours, no customers are allowed to enter the system but the system continues to operate until all customers are served. There are three servers in this system. Data from a single day of observing the system in the main post office at Auburn, Alabama have been collected. There are three queuing lines in the system, one for each server. Arriving customers select the shortest line and never switch lines. It has been proposed that the average waiting time per customer will be smaller in the one-line queuing system than in the three-line system. The main objectives of this case study are to validate this queuing model by using the multi-stage validation procedure, and then to compare the current three-line queuing system with the proposed one-line system.

In the first stage of the validation procedure, two important postulates of hypotheses need to be formulated: the probability distributions of the interarrival time of customers and the individual service time for each server. According to observed data from a single day, the following two hypotheses are made: (1) the interarrival time of customers is exponentially distributed, and (2) the service time for each server is normally distributed.

In the second stage, the chi-square goodness-of-fit test is applied to test the hypotheses made in the first stage. For the first hypothesis, i.e., H_0: the interarrival time of customers is exponentially distributed using a 5% significance level, let AT be the interarrival time of customers. The first 200 customers have been studied, and the average interarrival time for the 200 customers is 0.95 minute. The procedure of chi-square test is shown in Table 2. From Table 2, combining the last five groups, the sample chi-square statistic is 8.28 with five degrees of freedom, which is less than its critical value 11.07. Thus, we can not reject the first hypothesis. For the second hypothesis, i.e., H_0: the service time of the first server is normally distributed using a 5% significance level, let ST be the service time of the first server. The first 80 customers in Line 1 have been studied, and the mean and variance of the service time for the first server are 2.52 minutes and 0.21 (minute)^2, respectively. The procedure of chi-square test for the second hypothesis is shown in Table 3. From Table 3, the sample chi-square statistic is 8.40 with five degrees of freedom. Again, we can not reject the second hypothesis. We

Table 3. The Chi-square Test Procedure for the Service Time of the First Server

Value of ST	Probability	Expected No.	Observed No.
< 1.993	0.125	10	6
1.993 - 2.211	0.125	10	5
2.211 - 2.374	0.125	10	11
2.374 - 2.520	0.125	10	15
2.520 - 2.666	0.125	10	12
2.666 - 2.829	0.125	10	8
2.829 - 3.047	0.125	10	10
> 3.047	0.125	10	13
Total	1.000	80	80

Table 4. Variables with the Simulated Confidence Intervals and Actual Values

Variable	95% Confidence Interval	Actual Value
WT	(2.1363, 3.6257)	3.0185
TP	(462.38, 487.71)	483.32
NC	(486.24, 521.38)	513
U1	(0.9213, 0.9504)	0.9563
U2	(0.6519, 0.9061)	0.8974
U3	(0.7640, 0.8343)	0.8283

Table 5. Average Waiting Time for Three-line and One-line Queuing Systems.

Simulation Run	Three-line System	One-line System
1	4.68	4.67
2	4.68	2.42
3	2.57	2.05
4	3.09	2.00
5	1.96	1.69
6	3.88	5.34
7	1.32	2.07
8	3.49	1.85
9	1.87	2.27
10	2.63	2.36

can use the same procedure to test the service times of the second and third servers by changing the data. After conducting these tests, we conclude that the service times for all servers are normally distributed.

In the third stage, once the hypotheses have been verified, the simulation model can be established by writing a computer program. In this case study, we use SIMAN to write the simulation program. To test the degree to which the data generated by this model conform to the observed data, six variables have been selected. These variables are (1) average waiting time per customer, denoted by WT, (2) total time period per day, TP, (3) number of customers in the system per day, NC, (4) the utilization of server 1, U1, (5) the utilization of server 2, U2, and (6) the utilization of server 3, U3. Other variables may also be considered if appropriate, e.g., the average waiting time of customers in line 1, and so forth. From the observed data, the actual values of each variable can be calculated. For example, the number of customers in the system (NC) is 513 persons and the total waiting time of all customers is 1548.508 minutes; consequently, the average waiting time per customer (WT) is 1548.508 / 513 = 3.0185 minutes. After examining the SIMAN summary report, we can obtain 95% confidence interval for each variable from the simulation model by assuming the population of each corresponding variable is normally distributed. Table 4 shows the 95% confidence interval from the simulation model and the actual data for each variable from a particular single day. From Table 4, for each variable, with the exception of the utilization of server 1 (U1), the actual value is located on its corresponding 95% confidence interval. This reflects that the simulation model can predict the real conditions very well. If we reexamine the variable of U1, its actual value is very close to the upper bound of its corresponding 95% confidence interval. Actually, we can point out that the actual value of U1 is still smaller than 0.98206 which is the maximum value generated by the simulation model. Therefore, we will use this model to predict real conditions and to perform the analysis of comparison between the three-line queuing system and the proposed one-line system.

Comparison of Two Queuing Systems

To compare the current three-line queuing system with the proposed one-line system, we focus the interest on the average waiting time per customer. The result is displayed in Table 5. After performing a statistical test (two-sample t test) with the hypothesis H_0: the average waiting times per customer for 1-line and 3-line systems are equal, we can't say that the proposed one-line queuing system is better than the current three-line system.

CONCLUSIONS

It is hard to escape the conclusion that the purpose of a simulation experiment is to predict some aspects of reality. Computer simulation models are becoming increasingly popular these days as a tool for analyzing the behavior of complex systems. In the concept of validation, one is checking that the simulation model is working as intended. The multi-stage validation procedure is particularly useful in computer simulation models. When a model is simulated via a computer program, validation is very much like the debugging of any computer program. Therefore, validation is a necessary and important procedure for a simulation model and should be done carefully before the simulation experimentation is performed. Although the multi-stage validation procedure will not guarantee an absolutely valid model, it will make the model more representative of the real system and also more credible.

In this paper, we reviewed each step in the multi-stage validation procedure and then presented a case study to illustrate how to apply this validation procedure to validate the simulation model of a simple queuing system. The purpose of this presented case study is to develop a "statistically" valid simulation queuing model. However, statistics always has its own constraints, e.g., when using a sample statistic to conduct the hypothesis testing, one may need to assume the underlying distribution is normal. An experimenter should keep this point in mind when he is validating a simulation model.

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Journal of Management Studies 37:6 September 2000
0022-2380

INFLUENCES ON KNOWLEDGE PROCESSES IN ORGANIZATIONAL LEARNING: THE PSYCHOSOCIAL FILTER

Kate M. Andrews[1]

Brian L. Delahaye

Queensland University of Technology

ABSTRACT

This paper reports a segment of broader theory-building case study research exploring organizational learning and knowledge processes in a bio-medical consortium. Its focus is the individual-level factors that influence knowledge processes associated with organizational learning. As we explored how organizational learning occurred, the underlying knowledge processes came forward as complex and idiosyncratic. In an unanticipated finding, micro-processes emerged as highly influential, with individual perceptions of approachability, credibility and trustworthiness mediating *knowledge importing* and *knowledge sharing* activities. We introduce a model – *the psychosocial filter* – to describe the cluster of micro-processes that were brought forward in the study. Firstly, scientists filtered knowledge importing by deciding whom they would approach for information and from whom they would accept input. The individual's confidence to initiate information requests (which we termed social confidence) and the perceived credibility of knowledge suppliers both mediated knowledge importing. Secondly, scientists mediated knowledge sharing by actively deciding with whom they would share their own knowledge. Perceived trustworthiness – based on perceptions of what colleagues were likely to do with sensitive information – was the factor that influenced knowledge-sharing decisions. Significantly, the psychosocial filter seemed to constitute a heedful process with high functionality. Its effect was not to block knowledge circulation, but instead to ensure that knowledge-sharing decisions were made in a thoughtful and deliberate way. The psychosocial filter suggests an initial framework for conceptualizing the role that individual-level processes play in organizational knowledge sharing. Building on this, the model provides a platform for more focused exploration of knowledge processes and social relationships in organizational learning.

INTRODUCTION

Organizational learning is now accepted as a central, rather than peripheral organizational variable, with its competitive value widely recognized (Dodgson, 1993;

Address for reprints: Kate Andrews, Centre for Professional Practice in Education and Training, Queensland University of Technology, P.O. Box 577, Ashgrove 4060, Queensland, Australia.

Hamel and Prahalad, 1994; Miner and Mezias, 1996; Quinn, 1992). The concept of organizational learning is seen to have broad analytical value, because of its emphasis on dynamic, changing relationships (Dodgson, 1993) and emergent phenomena (Miner and Mezias, 1996). Whilst learning has long been part of the texture of organizational life (see March and Simon, 1958), its emergence as a significant economic variable has been fuelled by factors such as the speed of technological change, trends towards globalization and growing corporate competitiveness (Easterby-Smith et al., 1998). Furthermore, organizational learning is seen as a critical complement to managerial theory, because it is through learning that complexity is managed (Argyris, 1996). These factors combine to propel learning to the forefront of corporate competitiveness (De Geus, 1988), and have contributed to the explosion of research interest in the topic.

Organizational knowledge is a key component of organizational learning (see Dodgson, 1993; Huber, 1991), with organizational learning processes seen as specifically concerned with the growth and changes to knowledge (Duncan and Weiss, 1979, p. 87). Building on this, Huber (1991) described four knowledge constructs – knowledge acquisition, information distribution, information interpretation and organizational memory – as integrally linked to organizational learning.

More recently, there has been some concentration on factors related to what Huber termed knowledge distribution and acquisition. Specifically, knowledge contributing (sharing one's own knowledge) and knowledge adopting (importing knowledge from another source) have been nominated as core organizational learning processes (Goodman and Darr, 1998, p. 438). Turning initially to knowledge sharing, decisions to contribute knowledge were seen as related to the complexity of the problem on which information was sought, and related to this, the difficulties in articulating information (Goodman and Darr, 1998). Goodman and Darr also nominated factors that inhibited discretionary knowledge importing, including the time and effort involved, and the willingness to admit the need for help. Whilst Goodman and Darr have identified a range of factors which mediate knowledge exchanges, there has been little attention to the specific role psychological and social elements play in influencing knowledge transactions.

Also of interest to the present study is that Goodman and Darr's research focused on discretionary knowledge exchanges. In contrast, knowledge importing and sharing are essential features of one contemporary organizational form – the knowledge-creating company. The central characteristic of knowledge-creating companies is their dependence on significant incidences of problem solving using non-standardized knowledge (Alvesson, 1995). Consequently, in knowledge-creating companies knowledge is primarily related to individuals rather than built-in to organizational routines, work practices, machines or technologies (Alvesson, 1995). Furthermore, the problem solving and innovation that characterize knowledge-creating companies are unsolvable by any one person, instead requiring continual insights from a variety of perspectives (Cicourel, 1990). Knowledge-creating companies depend on collaborative and ongoing learning that involves the integration of multiple and differentiated forms of expertise (Tenkasi and Boland, 1996). Clearly, in contrast to the discretionary exchanges elaborated by Goodman and Darr (1998), knowledge importing and sharing are defining features of knowledge-creating companies. Factors that influence knowledge importing and sharing therefore emerge as of significant interest to organizational learning researchers.

Some recent research has contributed to understanding the issues affecting the collaborative problem-solving required in knowledge-creating companies. Specifically, McDonald and Ackerman (1998) studied the sourcing of expertise, and identified a two-stage process (expertise identification and expertise selection). From this work, and earlier contributions by Cicourel (1990), knowledge processes in knowledge-creating companies emerge as complex and highly differentiated. However, again there has been little emphasis on the micro, psychological and social processes that underpin knowledge-importing and knowledge-sharing activities.

The data analysed and the results reported in this paper were part of a larger project which conducted qualitative, theory-building research to explore organizational learning in a knowledge-creating company. Quite unexpectedly, individual-level factors emerged as exerting a strong influence on company knowledge processes. These unanticipated results related to the specific activities of knowledge importing and knowledge sharing. Thus the focus of this paper is the individual-level factors that influence knowledge processes associated with organizational learning.

THE STUDY SITE AND DATA

The study took place at Bio-Medical Consortium,[2] a partnership conducting research in areas such as growth factors, receptors and signal transduction, and clinical cytokine factors. The consortium comprised five joint-venture partners (medical research institutes, government scientific organizations and a commercial partner). Consortium projects allowed scientists to undertake biomedical research that extended beyond the capability of the partner organizations operating independently.

At the time that the research reported in this paper was conducted the consortium drew around 130 scientific staff from the partner organizations. Scientists collaborated on specified projects, but remained in the employ of their primary organizations, each of which operated within walking distance of the others. The consortium was founded on fluid project teams and scientists typically worked on one or more consortium projects whilst still retaining separate project responsibilities in their partner organization.

The data reported here was gathered in 15 individual semi-structured interviews with scientific staff representing the five partner organizations. As part of a broader organizational learning study not the subject of this paper, a specific example of actual organizational learning had previously been identified. The focus of the individual interviews was to explore how the specific incidence of organizational learning had occurred, as well as how organizational learning usually occurred in the consortium.

Seven senior scientists/managers, five scientists and four technicians/assistants comprised the interview sample. Interview duration ranged from 40 minutes to 90 minutes, with an average length of 70 minutes. Interviews were audio recorded, transcribed verbatim and content analysed. Data analysis and interpretation drew on the specific interview questions, as well as the unanticipated issues that emerged from the data itself.

The results reported in this paper were unanticipated in the study's design, but emerged quite clearly from the interview data itself. As scientists described their experience of organizational learning, knowledge circulation (comprising knowledge importing and knowledge sharing) came forward as mediated by a series of processes. We have constructed a tentative, descriptive model to capture our observations of the mediating processes that arose from the interviews. We propose the term *the psychosocial filter* to describe the factors which appeared to affect knowledge-importing (knowledge which the scientist obtained from an external source) and knowledge-sharing (personal knowledge which a scientist shared with someone else) decisions.

In deciphering and explaining the structure of the psychosocial filter, the present analysis was able to identify three areas of commonality in the themes brought forward by interview participants. The three clusters have been labelled *social confidence, perceived credibility* and *perceived trustworthiness*. The first two clusters were related to importing knowledge, and the third cluster described processes which influenced the scientists' knowledge sharing. Previewing the results to be discussed, figure 1 shows the three components of the psychosocial filter. The discussion will now move to the themes extracted from the scientists' discussions that suggested the psychosocial filter concept. The first area of discussion will be the two clusters of factors that appeared to influence knowledge importing.

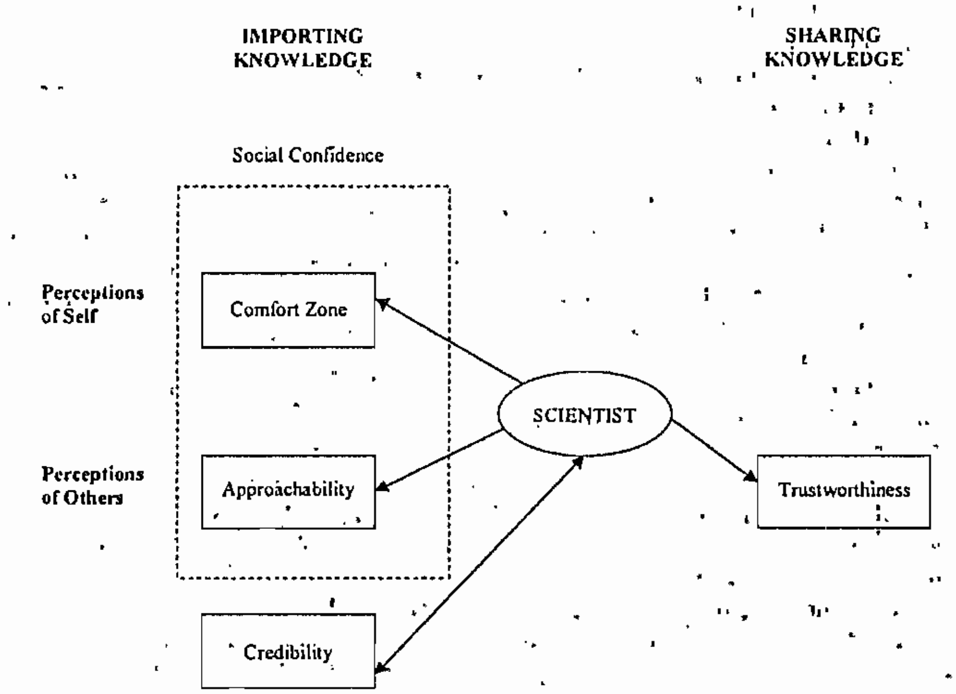

Figure 1. The psychosocial filter

Factors Mediating Knowledge Importing
As scientists discussed the knowledge importing which underpinned organizational learning, several themes emerged. Firstly, they described an active process: they deliberately mediated the knowledge acquisition process by deciding from whom they would seek out potentially useful information, and whose information inputs they were willing to accept. From the data, a model representing knowledge-importing processes has been derived. As shown in figure 1, knowledge importing comprised the social confidence of the prospective importer and the perceived credibility of potential knowledge sources.

Social confidence. Turning to the first factor that appeared to mediate knowledge importing, the term *social confidence* is used in the present research to describe an individual's ability to initiate working relationships with others. Social confidence itself seemed to comprise two overlapping constructs: the individual's personal *comfort zone* and the *perceived approachability* of information sources.

Scientists clearly identified difficulties in seeking out information when this involved moving outside the personal contacts with which they felt comfortable (i.e. moving outside their *comfort zone*). Initiating working relationships was not necessarily an expected competency of scientists: *people don't find it very easy* and the *whole practical side* of initiating potentially useful contacts was thought to be difficult.

> When you have to go to another institute and talk to strangers or ask opinions from people you don't know, you feel a bit out of your comfort zone. (Senior Scientist/Manager 3)

> It's very hard just to ring somebody up cold and say look, you know, 'I'm *x* from *y* and I'm having a problem with this. Can you help me?' And really they've got no obligation to help you, you're somebody they don't know. But it's a matter of having the gumption to just do that cold when you don't know these people. (Scientist 4)

> Maybe some people don't find it very easy, that whole thing of interacting with people that you don't know. I wonder sometimes if people do actually find just the whole practical side of the environment perhaps a bit harder than most. (Scientist 2)

In summary, the term comfort zone was used to describe the personal ease scientists felt in initiating working relationships. Those comfortable in a broad range of working relationships would be expected to have access to wider knowledge sources than peers who were less at ease initiating contact. However, additional factors further mediated decisions about which knowledge sources to pursue, and the discussion will now move to other aspects of the filter.

Scientists also regarded the perceived approachability of potential information sources as important in deciding from whom knowledge would be imported. The personal style and status of the potential information source was seen as a possible barrier to establishing linkages.

If you've met a person you've got some idea of how approachable they are. Because not everyone is approachable. I'm sure that there are people who think, 'Oh well, they're good, but I'll go and ask someone else.' (Scientist 1)

Sometimes they are intimidated by the specialists in the field. With a lot of the professors and the doctors, you feel a bit intimidated, like 'I can't go up to him or talk to him and ask him that.' (Scientist 3)

In contrast, knowing scientists on a personal level was thought to lubricate the knowledge-sharing process.

If you get to know people on a personal level, it's easier to deal with them on a business level at a later stage . . . it makes it a lot easier to contact people. (Technician/Assistant 3)

Of course, these preceding statements also indicate some covariance between perceived approachability and comfort zone, with scientists feeling more comfortable with those they regarded as approachable.

In summary of factors mediating knowledge-importing decisions, scientists described a range of processes that seemed to influence their ability to initiate working relationships with others – which was a necessary step in gaining access to information. The term social confidence has been used to describe the first factor, which clustered in two areas: the individual's personal comfort zone and the perceived approachability of the knowledge source. In this study, comfort zone seemed to reflect the individual's self-perception, while approachability was predominantly their perception of a second party (see figure 1). Whilst the two factors might be expected to co-vary, with feelings of comfort related to perceptions of approachability, at this early stage in theory development social confidence and perceived approachability have been retained as separate variables. Clearly, however, the texture of this factor is overtly interpersonal, and the interleaving of social and intellectual processes came forward quite clearly.

Scientists also described a second factor – the perceived credibility of the knowledge source – as affecting knowledge-importing decisions, and this is discussed in the next section.

Credibility of the knowledge source. The second psychosocial factor that appeared to impact on knowledge importing was the credibility of the information source. In the complex and dynamic environment that characterized this knowledge-creating company, differentiating useful from irrelevant knowledge was a problematic process that required active engagement. Reflecting this, scientists spoke of the need to filter information that may turn out to be *wrong or misleading*. Importantly, finding the *right person* was seen as fundamental, because the *quality of the information* depended on the *quality of the individual.*

It is the quality that does really count. I know for example there are individuals here that you would go to with a problem because you know that they are going to give you the right answer. Whereas another individual may give you an answer to it, [but] down the track it's going to be wrong or misleading or not as precise as you really looked for. You may not have confidence in it. And

> that to me is the big difference – the quality of the individual, and how good they are, and how good the information is that you get off them. (Scientist 4)

> Another issue is, and again this is a judgement issue, if you want to learn a technique you have to know who to go to . . . they'll ask somebody who may be very happy to give them an opinion, but is it the right person to give that opinion? You have to be able to filter information you get in. If you want to learn something you have to know where to go. You have to be able to make that judgement. And that's something that is difficult to get. (Senior Scientist/Manager 4)

Judging where to go for information was reported to be a difficult, personal decision. Others may have reached different judgements about a knowledge source's credibility, because it's *a very personal thing*.

> There are certain techniques that I would give little credence to as good ways of doing science at a technical level. So I would be less likely to collaborate with those people. But other people may say that very same group offers a fantastic opportunity. You know, it's a very personal thing. (Senior Scientist/Manager 4)

What seemed to come forward quite distinctly from these descriptions was that the credibility of knowledge was very much tied up with the credibility of the 'knower'.

In summary of the factors that mediated knowledge-importing decisions, receiving information inputs was an active process. Knowledge seekers deliberated about whom they should approach, a decision which seemed to rely on the two psychosocial constructs of social confidence and credibility of the source. Because the two processes appeared to mediate knowledge importing, their impact on the organizational learning process needs to be understood.

To date, the discussion has focused on micro-processes associated with importing knowledge. The focus now moves to the second element of the psychosocial filter, that of knowledge sharing.

Factors Mediating Knowledge Sharing

In the previous section micro-processes mediating knowledge importing were discussed, and the interleaving of social and intellectual factors came forward with some clarity.

Knowledge sharing was also a complex process, with knowledge holders actively making decisions about what knowledge they would share with whom, when. In fact, in the intensely competitive environment that characterized the research setting, knowledge was a valuable commodity that should not be shared casually. Whilst scientists worked collaboratively in multi-disciplinary, multi-partner teams they clearly recognized that individual reputation, status, career prospects, research grants and income were dependent on which ideas were attributed to them. Reflecting these factors, scientists spoke of the enormous personal impact of sharing knowledge unwisely: they could be *swallowed up*, *cut out of the chain*, and risked *losing credit*, *visibility*, first *authorship*, and a place on the patent. Therefore, *where does the glory go?* was an important consideration.

> You get swallowed up so you may not get credit for the idea that you produced. So that's always the worry. (Senior Scientist/Manager 4)

> 'Am I going to lose my visibility in this project? Am I going to lose my first authorship?' – very important. (Senior Scientist/Manager 1)

> I think people are still very scared of giving their things away where they'll get cut out of the chain if something is patented. Where does the glory go? (Technician/Assistant 2)

Because knowledge was seen as commercially valuable, and its ownership could be contested, knowledge sharing was not an automatic process. Instead, decisions on knowledge sharing needed to be made wisely. In the context of the rewards system in the present knowledge-creating company, being cautious about knowledge sharing was recognized by interviewees as commercially prudent: *a healthy selfishness*.

> It's a healthy selfishness in some ways, and they have to keep their eyes open. (Technician/Assistant 2)

> There is a lot of money riding on these things. So confidentiality obviously is a critical thing . . . I mean so often our patents are being written and there is money hanging on it so you've got to be careful about what you say to whom. (Scientist 4)

> Sometimes it's better to look after your own narrower interest. (Senior Scientist/Manager 2)

Thus what knowledge to share with whom, and when, arose as recurring and complex decisions. As the next section demonstrates, the perceived trustworthiness of colleagues was the important factor in making knowledge-sharing decisions.

Perceived trustworthiness. In the previous section, personal knowledge emerged as a valuable commodity that should not be shared casually. When faced with decisions about what knowledge to share with whom, scientists made judgements about the trustworthiness of their peers. The role of trust was seen as central: without trust, regardless of any formal knowledge-sharing requirements in place, scientists would not share knowledge.

> If you haven't got trust and confidence then it doesn't matter what else you've put in place, or what other structures you put in place to try and encourage co-operation, it's not going to happen. (Senior Scientist/Manager 1)

When scientists spoke about trust, they clearly described it as an issue that centred on the ownership of ideas. It was important for scientists to be able to trust others not to *radiate off* similar projects, or *reproduce work*. Defining trust in these terms was certainly congruent with the context in which the scientists operated, mirroring the commercial value of personal knowledge that was discussed earlier.

CONCLUSION

Our research selected a knowledge-creating company as a rich setting for the investigation of organizational learning and its associated knowledge processes. Knowledge-creating companies can be seen as pioneers, given their everyday emphasis on knowledge creation and learning. This paper reported findings from our broader qualitative, theory-building research in a bio-medical consortium.

Quite unexpectedly, the knowledge processes underpinning organizational learning emerged as complex and idiosyncratic, with micro-processes emerging as influential. Specifically, processes associated with knowledge circulation (comprising knowledge importing and knowledge sharing) were actively and personally mediated. We have introduced the term 'the psychosocial filter' to describe the cluster of micro-processes that came forward as mediating knowledge-importing and knowledge-sharing decisions.

Focusing initially on knowledge importing, individuals intuitively adopted filtering strategies as they made personal assessments about which scientists they would approach, and the credibility of potential suppliers of knowledge. Secondly, turning to knowledge sharing, scientists did not share their own knowledge unreflectively. Perceived trustworthiness – which was based distinctly on perceptions of what colleagues were likely to do with commercially sensitive information – emerged quite clearly as the psychosocial factor which determined with whom scientists were willing to share their own knowledge. The psychosocial filter can be imagined rather like a bubble around each individual, invisible but nevertheless influencing knowledge processes on the basis of whom the scientist was comfortable approaching; whom they regarded as credible, and whom they were willing to trust.

Significantly, the psychosocial filter seemed to constitute a heedful process with high functionality in the company under study. Its effect was not to block knowledge sharing, but instead to ensure that knowledge-sharing decisions were made in a thoughtful and deliberate way. We concur with Cicourel's (1990) proposition that these attributions of an interpersonal and professional nature, and judgements about others' competence, are normal rather than undesirable aspects of this type of work setting.

Finally, the psychosocial filter that emerged in this analysis suggests an initial framework for conceptualizing the role that individual-level processes play in organizational knowledge sharing. Building on this, the psychosocial filter provides a platform for more focused exploration of knowledge processes and social relationships in organizational learning.

國立雲林科技大學
九十學年度研究所博士班入學考試試題

所別：管理研究所
科目：企業管理文獻

Please read the article briefly. And getting its main theme, meaning of comcepts, and thinking logic as soon as possible. Then, offer us your opinions on the basis of this article only. (opinions from other materials are unnecessary)

1. How does the author construct his theoretic framework from literature review. Point out the main inductive logic. 25%

2. What research methods are used in this study. 25%

3. Please describe the meaning of all theoretic concepts (variables), and tell us how these concepts are supported by data analysis or phenomena interpretating. 30%

4. What knowledge you can get from this article. 20%

國立雲林科技大學
九十學年度研究所博士班入學考試試題
所別：管理研究所
科目：資訊管理文獻

Extending the Supply Chain

In the past, corporate strategy and value chain analysis looked primarily inside each company, searching for ways that a company's internal operations could provide competitive advantage. Today the focus is shifting outside corporate walls. Companies are looking for increased efficiencies in their links with suppliers, partners, and customers as new sources of competitive advantage. The internet, electronic data interchange (EDI), transportation and warehouse management software, and other related technologies are allowing companies to create electronic networks with suppliers and manufactures where they can management inventory that you can't see and don't own. A study conducted by the Performance Measurement Group found that companies that integrated their supply chains reported a 16 to 28 percent improvement in delivery performance, a 26 to 60 percent reduction in inventories, and a 30 o 50 percent improvement in fulfillment cycle time, as well as 10 to 16 percent increase in productivity.

Airbus Industrie, the European aerospace consortium, outsources the production of parts and the development of components to external supplies. Airbus is building a standard communication and collaboration platform for its four member companies (DA Airbus, British Aerospace, Aerospatiale, and the Spanish CASA) and their thousands of suppliers. The system will be used to support the development of its new 555-seat jetliner and is expected to reduce both production time and recurrent costs by 30 percent. Airbus is using Parametric Technology Corporation's product information automation system to store all data, including product geometry and parts of the bills of materials.

Office Depot has prospered by offering a wider range of stationery and office suppliers at lower cost than small retailers through just-in-time replenishment and tight inventory control systems. It uses information from a sophisticated demand forecasting system and point-of-sale data to replenish its inventory, placing 95 percent of its purchase orders directly to suppliers through EDI. Vendors who participate in the company's EDI program are supplied with weekly data about the sales performance of their products. Using these electronic links to Office Depot, most vendors can replenish inventory within one to two weeks, and often within a few days. Many suppliers use the EDI system to post advance shipment notifications to alert Office Deport that goods are about to be dispatched.

Instead of leaving the job of transporting goods to individual vendors, Office Depot hired a third-party freight optimizing service provider to consolidate deliveries and reduce transport costs. The service provider receives a copy of every purchase order Office Depot places with vendors and identifies opportunities to group inbound shipments together. If, instead of three trucks heading to Office Depot from Omaha, only one is required, Office Depot can realize additional savings. According to Bill Seltzer, Office Depot's chief information officer and executive vice president, improvements such as the inventory replenishment system have cut the company's distribution costs to 1 percent of total sales, down from 2 percent five years earlier.

Safeway, the third-largest supermarket chain in the United Kingdom, is using new supply chain management systems to speed the process of getting products from suppliers such as Birds Eye Wall's to customers. Safeway uses an IBM 4690 point-of-sale system to capture 800,000 consumer transactions daily, which are stored in a massive data warehouse running on an IBM ES/9000 mainframe. It developed its own software for making accurate and timely decisions about inventory replenishment, promotions, and production. Safeway shares this information about forecasts, inventory, and available shelf space electronically with its suppliers so that they can track demand for their products, adjust production, and calculate the size and timing of deliveries accordingly. Suppliers can also download the information into their enterprise resource planning (ERP) or production planning systems. The system also provides suppliers with news flashes about unanticipated demand and information on key contacts and contract terms. Suppliers in turn can use the system to send Safeway information about product availability, production capacity, inventory levels, and promotional proposals.

QUESTIONS:

1. Most managers are trained to manage a product line, a division, or an office. But under the trend toward establishing comprehensive, integrated systems among business partners (called industrial networks), they need to take a much broader view on both inside and outside their organizations. Please discuss the following questions. **(50%)**

   (1) Describe the business and technology drivers behind the growth of industrial networks.
   (2) How could industrial networks change organization and industry structure, management processes, technology platforms, and business capability?
   (3) Comment on major challenges industrial networks pose for businesses.

2. As indicated above, there are a number of companies that are quite positive and aggressive in improving relationships with suppliers and vendors by adopting EDI. As a management science expert, providing different opinions to decision makers is highly expected. Can you discuss the disadvantages of adopting EDI in organizations? An in-depth discussion is strongly recommended. **(50%)**

國立雲林科技大學
九十學年度研究所博士班入學考試試題

所別：管理研究所
科目：財務金融文獻

Read the paper of Miller's (1999) in the subsequent pages and write an essay associated with the paper judiciously. Your essay should include

1. Summarize the paper with your own words.
2. There are a few canonical fields of finance science mentioned in Miller's (1999). Tell the state of the art of at least of one of the field. (Certainly you can pick up the ones you are familiar with.)
3. Serve as a serious critic and comment on the Miller's paper.
4. As a young would-be finance professional, what are the implications of Miller's in your career pursuing?

Your score will be counted according to those four parts above. More precisely, each part is worth 25 points in your essay. Make your own view clear and optimize your time **(You have 100 minutes in this test)**.

國立雲林科技大學
九十學年度研究所博士班入學考試試題
所別：管理研究所
科目：財務金融文獻

The History of Finance

An eyewitness account.

Merton H. Miller

At five years, the German Finance Association is not very old as professional societies go, but then neither is the field of finance itself. Finance in its modern form really dates only from the 1950s. In the forty years since then, the field has come to surpass many, perhaps even most, of the more traditional fields of economics in terms of the numbers of students enrolled in finance courses, the numbers of faculty teaching finance courses, and above all in the quantity and quality of their combined scholarly output.

The huge body of scholarly research in finance over the last forty years falls naturally into two main streams. And no, I don't mean "asset pricing" and "corporate finance," but instead a deeper division that cuts across both. The division I have in mind is the more fundamental one between what I will call the *business school* approach to finance and the *economics department* approach. Let me say immediately, however, that my distinction is purely "notional," not physical — a distinction over what the field is really all about, not where the offices of the faculty happen to be located.

In the United States, the vast majority of academics in finance teach in business schools, not economics departments, and always have. At the same time, in the elite schools at least, a substantial fraction of the finance faculties have been trained in — that is, have received their Ph.D.s from — economics departments. Habits of thought acquired in graduate school have a tendency to stay with you.

MERTON H. MILLER is Robert R. McCormick distinguished service professor emeritus at the University of Chicago (IL 60637).

The characteristic business school approach tends to be what we would call in our jargon "micro normative." That is, a decision-maker, whether an individual investor or a corporate manager, is seen as maximizing some objective function, be it utility, expected return, or shareholder value, taking the prices of securities in the market as given. In a business school, after all, that's what you're supposed to be doing: teaching your charges how to make better decisions.

To someone trained in the classical traditions of economics, however, the dictum of the great Alfred Marshall stands out: "It is not the business of the economist to tell the brewer how to make beer." The characteristic economics department approach thus is not micro, but macro normative. The models assume a world of micro optimizers, and deduce from that how market prices, which the micro optimizers take as given, actually evolve.

Note that I am differentiating the stream of research in finance along macro versus micro lines, and not along the more familiar normative versus positive line. Both streams of research in finance are thoroughly positivist in outlook in that they try to be, or at least claim to be, concerned with testable hypotheses. The normal article in finance journals over the last forty years has two main sections: the first presenting the model, and the second an empirical section showing that real-world data are consistent with the model (which is hardly surprising, because had that not been so, the author would never have submitted the paper in the first place, and the editors would never have accepted the article for publication).

The interaction of these two streams, the business school stream and the economics department stream — the micro normative and the macro normative — has largely governed the history of the field of finance to date. I propose to review some of the highpoints of this history, taking full advantage of a handy organizing principle nature has given us: to wit, the Nobel Prizes in Finance.

Let me emphasize that I will not be offering a comprehensive survey of the field — the record is far too extensive for that — but rather a selective view of what I see as the highlights, an eyewitness account, as it were, and always with special emphasis on the tensions between the business school and the economics department streams.

After my overview, I offer some very personal views on where I think the field is heading, or at least where I would be heading were I just entering the field today.

MARKOWITZ AND THE THEORY OF PORTFOLIO SELECTION

The tension between the micro and macro approaches was visible from the very beginning of modern finance — from our big bang, as it were — which I think we can all agree today dates to the year 1952 with the publication in the *Journal of Finance* of Harry Markowitz's article, "Portfolio Selection." Markowitz in this remarkable paper gave, for the first time, a precise definition of what had hitherto been just vague buzzwords: risk and return.

Specifically, Markowitz then identified the yield or return on an investment with the expected value or probability-weighted mean value of its possible outcomes; and its risk with the variance or squared deviations of those outcomes around the mean. This identification of return and risk with mean and variance, so instinctive to finance professionals these days, was far from obvious then. The common perception of risk even today focuses on the likelihood of losses — on what the public thinks of as the "downside" risk — not just on the *variability* of returns.

Markowitz's choice of the variance as his measure of risk, counterintuitive as it may have appeared to many at the time, turns out to have been inspired. It not only subsumes the more intuitive view of risk — because in the normal or at least the symmetric distributions we use in practice the downside risk is essentially the mirror image of the upside — but it also has a property even more important for the development of the field. By identifying return and risk with mean and variance, Markowitz makes the powerful algebra of mathematical statistics available for the study of portfolio selection.

The immediate contribution of that algebra is the famous formula for the variance of a *sum* of random variables; that is, the weighted sum of the variance *plus* twice the weighted sum of the covariances. We in finance have been living on that formula, literally, for more than forty years now. That formula shows, among other things, that for the individual investor, the relevant unit of analysis must always be the whole portfolio, not the individual share. The risk of an individual share cannot be defined apart from its relation to the whole portfolio and, in particular, its covariances with the other components. Covariances, and not mere numbers of securities held, govern the risk-reducing benefits of diversification.

The Markowitz mean-variance model is the perfect example of what I call the business school or micro normative stream in finance. And this is somewhat ironic, in that the Markowitz paper was originally a thesis in the University of Chicago's economics department. Markowitz even notes that Milton Friedman, in fact, voted against the thesis initially on the grounds that it wasn't really economics.

And indeed, the mean-variance model, as visualized by Markowitz, really *wasn't* economics. Markowitz saw investors as actually applying the model to pick their portfolios using a combination of past data and personal judgment to select the needed means, variances, and covariances.

For the variances and covariances, at least, past data probably *could* provide at least a reasonable starting point. The precision of such estimates can always be enhanced by cutting the time interval into smaller and smaller intervals. But what of the means? Simply averaging the returns of the last few years, along the lines of the examples in the Markowitz paper (and later book) won't yield reliable estimates of the return *expected* in the future. And running those unreliable estimates of the means through the computational algorithm can lead to weird, corner portfolios that hardly seem to offer the presumed benefits of diversification, as any finance instructor who has assigned the portfolio selection model as a classroom exercise can testify.

If the Markowitz mean-variance algorithm is useless for selecting optimal portfolios, why do I take its publication as the starting point of modern finance? Because the essentially business school model of Markowitz was transformed by William Sharpe, John Lintner, and Jan Mossin into an economics department model of enormous reach and power.

WILLIAM SHARPE AND THE CAPITAL ASSET PRICING MODEL

That William Sharpe was so instrumental in transforming the Markowitz business school model into an economics department model continues the irony. Markowitz, it will be recalled, submitted his thesis to an economics department, but Sharpe was always a business school faculty member, and much of his earlier work had been in the management science/operations research area. Sharpe also maintains an active consulting practice advising pension funds on their portfolio selection problems. Yet his capital asset pricing model is almost as perfect an example as you can find of an economists' macro normative model of the kind I have described.

Sharpe starts by imagining a world in which every investor is a Markowitz mean-variance portfolio selector. And he supposes further that these investors all share the same expectation as to returns, variances, and covariances. But if the inputs to the portfolio selection are the same, then every investor will hold exactly the same portfolio of risky assets. And because all risky assets must be held by somebody, an immediate implication is that every investor holds the "market portfolio," that is, an aliquot share of every risky security in the proportions in which they are outstanding.

At first sight, of course, the proposition that everyone holds the same portfolio seems too unrealistic to be worth pursuing. Keep in mind first, however, that the proposition applies only to the holdings of risky assets. It does not assume that every investor has the same degree of risk aversion. Investors can always reduce the degree of risk they bear by holding riskless bonds along with the risky stocks in the market portfolio; and they can increase their risk by holding negative amounts of the riskless asset; that is, by borrowing and leveraging their holdings of the market portfolio.

Second, the idea of investing in the market portfolio is no longer strange. Nature has imitated art, as it were. Shortly after Sharpe's work appeared, the market created mutual funds that sought to hold all the shares in the market in their outstanding proportions. Such index funds, or "passive" investment strategies, as they are often called, are now followed by a large and increasing number of investors, particularly by U.S. pension funds.

The realism or lack of realism of the assumptions underlying the Sharpe CAPM has never been a subject of serious debate within the profession, unlike the case of the Modigliani and Miller propositions to be considered later. The profession, from the outset, wholeheartedly adopted the Friedman positivist view: that what counts is not the literal accuracy of the assumptions, but the *predictions* of the model.

In the case of Sharpe's model, these predictions are striking indeed. The CAPM implies that the distribution of expected rates of return across all risky assets is a *linear* function of a single variable, namely, each asset's sensitivity to or covariance with the market portfolio, the famous beta, which becomes the natural measure of a security's risk. The aim of science is to explain a lot with a little, and few models in finance or economics do so more dramatically than the CAPM.

The CAPM not only offers new and powerful theoretical insights into the nature of risk, but also lends itself admirably to the kind of in-depth empirical investigation so necessary for the development of a new field like finance. And its benefits have not been confined narrowly to the field of finance. The great volume of empirical research testing the CAPM has led to major innovations in both theoretical and applied econometrics.

Although the single-beta CAPM managed to withstand more than thirty years of intense econometric investigation, the current consensus within the profession is that a single risk factor, although it takes us an enormous length of the way, is not quite enough for describing the cross-section of expected returns. Besides the market factor, two other pervasive risk factors have by now heen identified for common stocks.

One is a size effect; small firms seem to earn higher returns than large firms, on average, even after controlling for beta or market sensitivity. The other is a factor, still not fully understood, but that seems reasonably well captured by the ratio of a firm's accounting book value to its market value. Firms with high book-to-market ratios appear to earn higher returns on average over long horizons than those with low book-to-market ratios after controlling for size and for the market factor.

That a three-factor model has now been shown to describe the data somewhat better than the single-factor CAPM should detract in no way, of course, from appreciation of the enormous influence of the original CAPM on the theory of asset pricing.

THE EFFICIENT MARKETS HYPOTHESIS

The mean-variance model of Markowitz and the CAPM of Sharpe et al. are contributions whose great scientific value was recognized by the Nobel Committee in 1990. A third major contribution to finance was recognized at the same time. But before describing it, let me mention a fourth major contribution that has done much to shape the development of the field of finance in the last twenty-five years, but that has so far not received the attention from the Nobel Committee I believe it deserves.

I refer, of course, to the efficient markets hypothesis, which says, in effect, that no simple rule based on already published and available information can generate above-normal rates of return. On this score of whether mechanical profit opportunities exist, the conflict between the business school tradition in finance and the economics department tradition has been and still remains intense.

The hope that studying finance might open the way to successful stock market speculation served to support interest in the field even before the modern scientific foundations were laid in the 1950s. The first systematic collection of stock market prices, in fact, was compiled under the auspices of the Alfred Cowles Foundation in the 1930s.

Cowles had a lifelong enthusiasm for the stock market, dimmed only slightly by the catastrophic crash of 1929. The Cowles Foundation, currently an adjunct of the Yale University economics department, was the source of much fundamental research on econometrics in the 1940s and '50s.

The Cowles indexes of stock prices have long since been superseded by much more detailed and computerized data bases, such as those of the Center for Research in Security Prices at the University of Chicago. And to those computer data bases, in turn, goes much of the credit for stimulating the empirical research in finance that has given the field its distinctive flavor.

Even before these new computerized data bases came into widespread use in the early 1960s, however, the mechanical approach to above-normal investment returns was already being seriously challenged. The challenge was delivered, curiously enough, not by economists, but by statisticians like M.G. Kendall and my colleague, Harry Roberts — who argued that stock prices are essentially random walks. This implies, among other things, that the record of past stock prices, however rich in "patterns" it might appear, has no predictive power for future stock returns.

By the late 1960s, however, the evidence was accumulating that stock prices are not random walks by the strictest definition of that term. Some elements of predictability *could* be detected, particularly in long-run returns. The issue of whether publicly available information could be used for successful stock market speculation had to be rephrased — a task in which my colleague, Eugene Fama, played the leading role — as whether the observed departures from randomness in the time series of returns on common stocks represent true profit opportunities after transaction costs and after appropriate compensation for changes in risk over time. With this shift in focus from returns to cost- and risk-adjusted returns, the efficient markets debate becomes no longer a matter of statistics, but one of economics.

This connection with economics helps explain why the efficient markets hypothesis of finance remains as strong as ever, despite the steady drumbeat of empirical studies directed against it. If you find some mechanical rule that seems to earn above-normal returns — and with thousands of researchers spinning through the mountains of tapes of past data, anomalies, like the currently fashionable "momentum effects," are bound to keep turning up — then imitators will enter and compete away those above-normal returns exactly as in any other setting in economics. Above-normal profits, wherever they are found, inevitably carry with them the seeds of their own decay.

THE MODIGLIANI-MILLER PROPOSITIONS

Still other pillars on which the field of finance rests are the *Modigliani-Miller propositions* on capital structure. Here, the tensions between the micro normative and the macro normative approaches were evident from the outset, as is clear from the very title of the first M&M paper, "The Cost of Capital, Corporation Finance and the Theory of Investment." The theme of that paper, and indeed of the whole field of corporate finance at the time, is capital budgeting.

The micro normative wing was concerned with finding the "cost of capital," in the sense of the optimal cutoff rate for investment when the firm can finance the project either with debt or equity or some combination of both. The macro normative or economics wing sought to express the aggregate demand for investment by corporations as a function of the cost of capital that firms are actually using as their optimal cutoffs, rather than just the rate of interest on long-term government bonds.

The M&M analysis provided answers, but ones that left both wings of the profession dissatisfied. At the macro normative level, the M&M measure of the cost of capital for aggregate investment functions never really caught on, and, indeed, the very notion of estimating aggregate demand functions for investment has long since been abandoned by macro economists. At the micro level, the M&M propositions imply that the choice of financing instrument is irrelevant for the optimal cutoff. Such a cutoff is seen to depend solely on the risk (or "risk class") of the investment, regardless of how it is financed, hardly a happy position for professors of finance to explain to their students being trained, presumably, in the art of selecting optimal capital structures.

Faced with the unpleasant action consequences of the M&M model at the micro level, the tendency of many at first was to dismiss the assumptions underlying M&M's then-novel arbitrage proof as unrealistic. The assumptions underlying the CAPM, of course, are equally or even more implausible, as noted earlier, but the profession seemed far more willing to accept Friedman's "the assumptions don't matter" position for the CAPM than for the M&M propositions.

The likely reason is that the second blade of the Friedman positivism slogan — what *does* count is the descriptive power of the model itself — was not followed up. Tests by the hundreds of the CAPM fill the literature. But direct calibration tests of the M&M propositions and their implications do not.

One fundamental difficulty of testing the M&M propositions shows up in the initial M&M paper itself. The capital structure proposition says that if you could find two firms whose underlying earnings are identical, then so would be their market values, regardless of how much of the capital structure takes the form of equity as opposed to debt.

But how do you find two companies whose earnings are identical? M&M tried using industry as a way of holding earnings constant, but this sort of filter is far too crude. Attempts to exploit the power of the CAPM for testing M&M were no more successful. How do you compute a beta for the underlying real assets?

One way to avoid the difficulty of not having two identical firms, of course, is to see what happens when the *same* firm changes its capital structure. If a firm borrows and uses the proceeds to pay its shareholders a huge dividend or to buy back shares, does the value of the firm increase? Many studies have suggested that it does. But the interpretation of such results faces a hopeless identification problem.

The firm, after all, never issues a press release saying "we are just conducting a purely scientific investigation of the M&M propositions." The market, which is forward-looking, has every reason to believe that the capital structure decisions are conveying management's views about changes in the firm's prospects for the future. These confounding "information effects," present in every dividend and capital structure decision, render indecisive all tests based on specific corporate actions.

Nor can we hope to refute the M&M propositions indirectly by calling attention to the multitude of new securities and of variations on old securities that are introduced year after year. The M&M propositions say only that no gains could be earned from such innovations if the market were in fact "complete." But the new securities in question may well be serving to complete the market, earning a first-mover's profit to the particular innovation. Only those in Wall Street know how hard it is these days to come by those innovator's profits.

If all this seems reminiscent of the efficient markets hypothesis, that is no accident. The M&M propositions are also ways of saying that there is no free lunch. Firms cannot hope to gain by issuing what looks like low-cost debt rather than high-cost equity. They just make the cost of higher-cost equity even higher. And if any substantial number of firms, at the same time, seek to replace what they think is their high-cost equity with low-cost debt (even tax-advantaged debt), then the interest costs of debt will rise, and the required yields on equity will fall until the perceived incentives to change capital structures (or dividend policies for that matter) are eliminated.

The M&M propositions, in short, like the efficient markets hypothesis, are about *equilibrium* in the capital markets — what equilibrium looks like, and what forces are set in motion once it is disturbed. And this is why neither the efficient markets hypothesis nor the Modigliani-Miller propositions have ever set well with those in the profession who see finance as essentially a branch of management science.

OPTIONS

Fortunately, however, recent developments in finance, also recognized by the Nobel Committee, suggest that the conflict between the two traditions in finance, the business school stream and the economics department stream, may be on the way to reconciliation.

This development, of course, is the field of options, whose pioneers, recently honored by the Nobel Committee, were Robert Merton and Myron Scholes (with the late Fischer Black everywhere acknowledged as the third pivotal figure). Because the intellectual achievement of their work has been commemorated over and over — and rightly so — I will not seek to review it here. Instead, in keeping with my theme, I want to focus on what options mean for the history of finance.

Options mean, among other things, that for the first time in its close to fifty-year history, the field of finance can be built, or as I will argue be rebuilt, on the basis of "observable" magnitudes. I still remember the teasing we financial economists, Harry Markowitz, William Sharpe, and I, had to put up with from the physicists and chemists in Stockholm when we conceded that the basic unit of our research, the expected rate of return, was not actually observable. I tried to parry by reminding them of their neutrino — a particle with no mass whose presence is inferred only as a missing residual from the interactions of other particles. But that was eight years ago. In the meantime, the neutrino has been detected.

To say that option prices are based on observables is not strictly true, of course. The option price in the Black-Scholes-Merton formula depends on the current market value of the underlying share, the striking price, the time to maturity of the contract, and the risk-free rate of interest, all of which are observable either exactly or very closely. But the option price depends also, and very critically, on the variance of the distribution of returns on the underlying share, which is not directly observable; it must be estimated.

Still, as Fischer Black always reminded us, estimating variances is orders of magnitude easier than estimating the means or expected returns that are central to the models of Markowitz, Sharpe, or Modigliani-Miller. The precision of an estimate of the variance can be improved, as noted earlier, by cutting time into smaller and smaller units — from weeks to days to hours to minutes. For means, however, the precision of estimate can be enhanced only by lengthening the sample period, giving rise to the well-known dilemma that by the time a high degree of precision in estimating the mean from past data has been achieved, the mean itself has almost surely shifted.

Having a base in observable quantities — or virtually observable quantities — on which to value securities might seem at first sight to have benefited primarily the management science stream in finance. And indeed, recent years have seen the birth of a new and rapidly growing specialty area within the profession, that of financial engineering (and the recent establishment of a journal with that name is a clear sign that the field is here to stay). The financial engineers have already reduced the original Black-Scholes-Merton formula to Model-T status.

Nor has the micro normative field of *corporate* finance been left out. When it comes to capital budgeting, long a major focus of corporate finance, the decision impact of what have come to be called "real" options — even simple ones like the right to close down a mine when the output price falls and reopen it when it rises — is substantially greater than that of variations in the cost of capital.

The options revolution, if I may call it that, is also transforming the macro normative or economics stream in finance. The hint of things to come in that regard is prefigured in the title of the original Black-Scholes paper, "The Pricing of Options and Corporate Liabilities." The latter phrase was added to the title precisely to convince the editors of the *Journal of Political Economy* — about as economics a journal as you can get — that the original (rejected) version of the paper was not just a technical *tour de force* in mathematical statistics, but an advance with wide application for the study of market prices.

And indeed, the Black-Scholes analysis shows, among other things, how options serve to "complete the market" for securities by eliminating or at least substantially weakening the constraints on high leverage obtainable with ordinary securities. The Black-Scholes demonstration that the shares in highly leveraged corporations are really call options also serves in effect to complete the M&M model of the pricing of corporate equities subject to the prior claims of the debtholders. We can go even further: *Every* security can be thought of as a package of component Arrow-Debreu state-price contingent claims (options, for short), just as every physical object is a package of component atoms and molecules.

RECONSTRUCTION OF FINANCE?

I will speculate no further about these and other exciting prospects for the future. Let me close rather with a question: What would I advise a young member of the German Finance Association to specialize in? What would I specialize in if I were starting over and entering the field today?

Well, I certainly wouldn't go into asset pricing or corporate finance. Research in those subfields has already reached the phase of rapidly diminishing returns. Agency theory, I would argue, is best left to the legal profession, and behavioral finance is best left to the psychologists. So, at the risk of sounding a bit like the character in the movie "The Graduate," I reduce my advice to a single word: options.

When it comes to research potential, options have much to offer both the management science/business school wing within the profession *and* the economics wing. In fact, so vast are the research opportunities for both wings that the field is surely due for a total reconstruction as profound as that following the original breakthrough by Harry Markowitz in 1952.

The shift toward options as the center of gravity of finance that I foresee should be particularly welcomed by the members of the German Finance Association. I can remember when research in finance in Germany was just beginning and tended to consist of replication of American studies using German data. But when it comes to a relatively new area like options, we all stand roughly equal at the starting line. And this is an area in which the rigorous and mathematical German academic training may even offer a comparative advantage.

It is no accident, I believe, that the Deutsche Termin Borse (or Eurex, as it has now become after merging with the Swiss exchange) has taken the high-tech road to a leading position among the world's futures exchanges only eight years after a great conference in Frankfurt where Hartmut Schmidt, Fischer Black, and I sought to persuade the German financial establishment that allowing futures and options trading would not threaten the German economy. Hardware and electronic trading were the key to DTB's success, but I see no reason why the German scholarly community cannot duplicate that success on the more abstract side of research in finance as well.

Whether it can should be clear by the time of the twenty-fifth annual meeting. I'm only sorry I won't be able to see that happy occasion.

ENDNOTE

This is a slightly modified version of an address delivered at the Fifth Annual Meeting of the German Finance Association in Hamburg on September 25, 1998.