CPC International

(SCENARIO)

(STRATEGY)		1	2	3	4	5	6
EPDV		366.213940	177.698330	667.454130	420.190720	545.158220	298.596720
SD		192.108270	131.258010	120.891100	84.244514	215.119260	177.003520
PVMAX	1	604.388760	355.522520	831.590900	560.573720	810.263140	530.027060
PVMIN		58.036022	58.676301	410.301040	231.365890	191.030680	60.677711
CUMMIN		57.109642	51.154881	59.780001	59.780001	59.780001	58.780401
EPDV		340.143920	131.895600	650.586940	375.218110	533.056820	260.214870
SD		192.050130	121.586790	118.500960	75.446725	216.714550	171.698970
PVMAX	2	573.706630	296.468380	794.820180	492.970500	795.620530	483.084500
PVMIN		18.757021	15.208665	406.493140	208.531020	163.340520	21.236437
CUMMIN		15.502740	10.440481	43.780001	43.780001	43.780001	16.995001
EPDV		369.329610	151.287410	794.680340	515.735180	649.038170	368.105470
SD		265.372410	195.097160	206.736310	166.013740	312.533290	270.196210
PVMAX	3	695.198940	410.840030	1124.851100	815.537080	1018.670400	704.241660
PVMIN		−62.536112	−72.443578	356.588250	146.496890	96.958935	−55.322096
CUMMIN		−75.780858	−90.075141	25.780001	2.845201	1.345802	−71.575399
EPDV		353.507560	145.259230	663.950580	388.581740	546.420460	273.578510
SD		192.050130	121.586790	118.500960	75.446725	216.714550	171.698970
PVMAX	4	587.070260	309.832010	808.183820	506.334140	808.984170	496.448140
PVMIN		32.120656	28.572301	419.856780	221.894660	176.704160	34.600074
CUMMIN		29.502740	24.440481	50.780001	50.780001	50.780001	30.995001
EPDV		359.115070	145.601000	737.050700	458.787300	601.626680	324.344740
SD		228.999980	158.518470	167.104560	125.582430	271.477090	228.026660
PVMAX	5	639.333980	358.166600	983.894540	677.206280	928.652240	614.727300
PVMIN		−17.902321	−24.999035	387.425030	182.291890	134.617870	−12.943491
CUMMIN		−23.774518	−33.899039	25.780001	25.780001	25.780001	−20.789999
EPDV		334.536420	131.853830	577.486830	305.012550	477.850600	209.448640
SD		155.328290	85.546303	75.942837	31.174032	162.754560	116.747750
PVMAX	6	521.442910	248.133790	619.109470	322.098370	675.952450	364.805340
PVMIN		68.780001	68.780001	438.924880	248.133790	205.426810	68.780001
CUMMIN		68.780001	68.780001	68.780001	68.780001	68.780001	68.780001

Grain Processing

(STRATEGY)		(SCENARIO) 1	2	3	4	5	6
EPDV		167.476540	99.546404	324.387660	238.992510	261.282450	174.169980
SD		100.285160	80.923154	81.784009	70.332795	119.063080	108.322160
PVMAX	1	294.616190	208.114170	463.797740	369.225360	408.701390	313.307870
PVMIN		17.176021	12.816301	149.549800	83.957540	68.993179	19.817709
CUMMIN		16,249640	10.294880	18.920000	18.920000	18.920000	17.920400
EPDV		141.406530	53.743670	307.520470	194.019890	249.181050	135.788130
SD		99.929805	71.355315	77.296544	60.563236	120.564440	103.247080
PVMAX	2	263.934060	149.060020	427.027030	301.622150	394.058770	266.365310
PVMIN		−22.102980	−25.651335	145.741890	61.122665	41.303017	−19.623564
CUMMIN		−25.357260	−30.419520	2.920000	2.920000	2.920000	−23.865000
EPDV		170.592210	73.135485	451.613870	334.536980	365.162400	243.678730
SD		173.673820	145.901250	170.336800	153.158270	217.771620	203.669080
PVMAX	3	385.426380	263.431680	757.057960	624.188740	617.108640	487.522460
PVMIN		−103.396110	−113.303580	95.837002	−0.911463	−25.078573	−96.182096
CUMMIN		−116.640860	−130.935140	−15.080000	−78.874800	−80.374200	−112.435400
EPDV		154.770160	67.107307	320.884110	207.383530	262.544680	149.151760
SD		99.929805	71.355315	77.296544	60.563236	102.564440	103.247080
PVMAX	4	277.297700	162.423660	440.390670	314.985790	407.422410	279.728940
PVMIN		−8.739344	−12.287699	159.105530	74.486302	54.666653	−6.259927
CUMMIN		−11.357260	−16.419520	9.920000	9.920000	9.920000	−9.865000
EPDV		160.377670	67.449076	393.984220	277.589080	317.750910	199.917990
SD		137.104530	108.889160	128.862180	111.955450	175.969170	160.434010
PVMAX	5	329.561420	210.758250	616.101370	485.857920	527.090490	398.008090
PVMIN		−58.762323	−65.859035	126.673790	34.883535	12.590364	−53.803492
CUMMIN		−64.634521	−74.759039	−15.080000	−30.160000	−30.374200	−61.650000
EPDV		135.799020	53.401901	234.420360	123.814340	193.974820	85.021895
SD		63.052715	34.725977	30.827624	12.654537	66.067278	47.391644
PVMAX	6	211.670330	100.725430	251.316320	130.750020	274.390700	148.086150
PVMIN		27.920000	27.920000	178.173630	100.725430	83.389307	27.920000
CUMMIN		27.920000	27.920000	27.920000	27.920000	27.920000	27.920000

Hubinger

(STRATEGY)		(SCENARIO) 1	2	3	4	5	6
EPDV		93.351286	70.397228	196.430420	171.409030	155.402210	127.761170
SD		66.359077	62.351208	69.099026	65.728722	83.609303	82.993167
PVMAX	1	179.076940	153.133670	326.617920	297.856080	258.926520	232.475740
PVMIN		1.936020	−2.423699	52.294559	28.977038	23.475519	4.577709
CUMMIN		1.009640	−4.945120	3.680000	3.680000	3.680000	2.680400
EPDV		67.281273	24.594494	179.563230	126.436420	143.300810	89.379326
SD		65.682376	52.908692	63.308449	55.574398	85.014847	78.125295
PVMAX	2	148.394810	94.079519	289.847200	230.252870	244.283910	185.533180
PVMIN		−37.342979	−40.891336	48.486656	6.142164	−4.214642	−34.863563
CUMMIN		−40.597260	−45.659521	−12.320000	−24.640000	−24.747100	−39.105000
EPDV		96.466956	43.986308	323.656620	266.953500	259.282160	197.269930
SD		139.666740	127.877840	157.916650	148.669790	182.944030	179.405200
PVMAX	3	269.877130	208.451180	619.878140	552.819450	467.333780	406.690340
PVMIN		−118.636120	−128.543580	−1.418235	−55.891964	−70.596231	−111,422100
CUMMIN		−131.880860	−146.175140	−30.320000	−109.354800	−110.854200	−127.675400
EPDV		80.644910	37.958131	192.926860	139.800050	156.664440	102.742960
SD		65.682376	52.908692	63.308451	55.574398	85.014846	78.125295
PVMAX	4	161.758440	107.443160	303.210840	243.616500	257.647540	198.896810
PVMIN		−23.979344	−27.527700	61.850292	19.505800	9.148994	−21.499928
CUMMIN		−26.597260	−31.659520	−5.320000	−10.640000	−10.747100	−25.105000
EPDV		86.252414	38.299900	266.026980	210.005610	211.870660	153.509190
SD		103.003460	90.716690	115.871480	107.249000	140.759460	135.679760
PVMAX	5	214.022160	155.777750	478.921550	414.488640	377.315620	317.175970
PVMIN		−74.002323	−81.099037	29.418550	−20.096967	−32.937296	−69.043490
CUMMIN		−79.874520	−89.999042	−30.320000	−60.640000	−60.854200	−76.890000
EPDV		61.673768	24.252726	106.463110	56.230868	88.094584	38.613096
SD		28.635689	15.770967	14.000511	5.747118	30.004767	21.523139
PVMAX	6	96.131084	45.794931	114.136490	59.380740	124.615830	67.254023
PVMIN		12.680000	12.680000	80.918399	45.744931	37.871648	12.680000
CUMMIN		12.680000	12.680000	12.680000	12.680000	12.680000	12.680000

National Starch
(SCENARIO)

(STRATEGY)		1	2	3	4	5	6
EPDV		87.222821	67.987257	185.851280	165.821430	146.648330	123.924230
SD		63.577790	60.826310	68.130616	65.366228	80.702233	80.914318
PVMAX	1	169.524480	148.588040	315.276280	291.955470	246.543560	225.792770
PVMIN		0.676021	−3.683699	44.253772	24.431467	19.712248	3.317709
CUMMIN		−0.250360	−6.205120	2.420000	2.420000	2.420000	1.420400
EPDV		61.152808	22.184524	168.984080	120.848810	134.546930	85.542378
SD		62.859189	51.400138	62.214921	55.180451	82.095735	76.070703
PVMAX	2	138.842350	89.533889	278.505570	224.352260	231.900950	178.850210
PVMIN		−38.602979	−42.151336	40.445869	1.596533	−7.977913	−36.123563
CUMMIN		−41.857259	−46.919520	−13.580000	−27.160000	−27.267100	−40.365000
EPDV		90.338490	41.576338	313.077480	261.365890	250.528280	193.432980
SD		136.864300	126.399910	156.926550	148.307020	180.086340	177.419420
PVMAX	3	260.334670	203.905550	608.536490	546.918840	454.950820	400.007370
PVMIN		−119.896110	−129.803580	−9.459023	−60.437595	−74.359503	−112.682100
CUMMIN		−133.140860	−147.435140	−31.580000	−111.874800	−113.374200	−128.935400
EPDV		74.516444	35.548161	182.347720	134.212450	147.910560	98.906014
SD		62.859188	51.400138	62.214921	55.180451	82.095734	76.070703
PVMAX	4	152.205980	102.897530	291.869200	237.715900	245.264580	192.213850
PVMIN		−25.239343	−28.787699	53.809505	14.960170	5.385724	−22.759928
CUMMIN		−27.857260	−32.919520	−6.580000	−13.160000	−13.267100	−26.365000
EPDV		80.123948	35.889929	255.447830	204.418000	203.116790	149.672240
SD		100.193750	89.228816	114.842030	106.870590	137.868150	133.652040
PVMAX	5	204.469710	151.232110	467.579910	408.588030	364.932660	310.493000
PVMIN		−75.262323	−82.359036	21.377763	−24.642598	−36.700567	−70.303491
CUMMIN		−81.134520	−91.259040	−31.580000	−63.160000	−63.374200	−78.150000
EPDV		55.545303	21.842755	95.883973	50.643259	79.340706	34.776148
SD		25.790187	14.203821	12.609293	5.176032	27.023221	19.384405
PVMAX	6	86.578627	41.199300	102.794860	53.480131	12.232870	60.571053
PVMIN		11.420000	11.420000	72.877612	41.199300	34.108378	11.420000
CUMMIN		11.420000	11.420000	11.420000	11.420000	11.420000	11.420000

Pennick & Ford

(STRATEGY)		(SCENARIO) 1	2	3	4	5	6
EPDV		111.931240	77.703650	228.503690	188.349250	181.941750	139.393830
SD		74.820756	66.986230	72.119586	66.845519	92.451797	89.312994
PVMAX	1	208.037570	166.914870	361.002890	315.745230	296.468510	252.736810
PVMIN		5.756020	1.396301	76.672184	42.758240	34.884801	8.397709
CUMMIN		4.829640	−1.125120	7.500000	7.500000	7.500000	6.500400
EPDV		85.861226	31.900916	211.636500	143.376630	169.840340	101.011980
SD		74.251978	57.501405	66.691570	56.787148	93.888838	84.379858
PVMAX	2	177.355430	107.860720	324.232170	248.142020	281.825900	205.794250
PVMIN		−33.522979	−37.071336	72.864282	19.923366	7.194640	−31.043564
CUMMIN		−36.777259	−41.839520	−8.500000	−17.000000	−17.107100	−35.285000
EPDV		115.046910	51.292730	355.729900	283.893710	285.821700	208.902580
SD		148.173050	132.371080	160.954650	149.777580	191.630880	185.446360
PVMAX	3	298.847760	222.232380	654.263110	570.708600	504.875780	426.951410
PVMIN		−114.816110	−124.723580	22.959390	−42.110763	−59.186949	−107.602100
CUMMIN		−128.060860	−142.355140	−26.500000	−101.714800	−103.214200	−123.855400
EPDV		99.224862	45.264552	225.000140	156.740270	183.203980	114.375610
SD		74.251978	57.501405	66.691571	56.787148	93.888838	84.379859
PVMAX	4	190.719070	121.224360	337.595810	261.505660	295.189540	219.157890
PVMIN		−20.159343	−23.707699	86.227918	33.287003	20.558277	−17.679928
CUMMIN		−22.777260	−27.839520	−1.500000	−3.000000	−3.107100	−21.285000
EPDV		104.832370	45.606320	298.100250	226.945820	238.410200	165.141840
SD		111.532880	95.243089	119.037460	108.406566	149.546820	141.847230
PVMAX	5	242.982790	169.558950	513.306530	432.377790	414.857610	337.437040
PVMIN		−70.182323	−77.279037	53.796175	−6.315765	−21.528014	−65.223491
CUMMIN		−76.054520	−86.179040	−26.500000	−53.000000	−53.214200	−73.070000
EPDV		80.253720	31.559146	138.536390	73.171082	114.634120	50.245748
SD		37.262529	20.522157	18.218331	7.478505	39.044057	28.007240
PVMAX	6	125.091710	59.526133	148.521460	77.269891	162.157830	87.515093
PVMIN		16.500000	16.500000	105.296020	59.526133	49.280931	16.500000
CUMMIN		16.500000	16.500000	16.500000	16.500000	16.500000	16.500000

Staley

(STRATEGY)		(SCENARIO) 1	2	3	4	5	6
EPDV		287.418790	178.898830	533.599920	396.963190	435.565940	296.300640
SD		161.952080	130.500320	135.220580	117.298450	191.729960	174.269260
PVMAX	1	491.218180	352.844080	766.398440	615.136910	671.145320	518.426160
PVMIN		30.699001	23.896862	241.852070	137.131910	113.251070	34.820627
CUMMIN		29.253640	19.962880	33.420000	33.420000	33.420000	31.860400
EPDV		261.348770	133.096100	516.732730	351.990570	423.464540	257.918790
SD		161.585750	120.990210	130.304350	107.357240	193.212330	169.231660
PVMAX	2	460.536050	293.789930	729.627720	547.533690	656.502700	471.483600
PVMIN		−8.580000	−14.570775	238.044170	144.297040	85.560905	−4.620646
CUMMIN		−12.353260	−20.751520	17.420000	17.420000	17.420000	−9.925000
EPDV		290.534460	152.487910	660.826130	492.507660	539.445890	365.809390
SD		235.431390	195.541900	223.789350	200.142680	290.332780	269.442500
PVMAX	3	582.028380	408.161590	1059.658600	870.100270	879.552570	692.640760
PVMIN		−89.873132	−102.223020	188.139280	52.262909	19.179316	−81.179179
CUMMIN		−103.636860	−121.267140	−0.580000	−49.834800	−51.494201	−98.495400
EPDV		274.712410	146.459730	530.096370	365.354220	436.828180	271.282430
SD		161.585750	120.990210	130.304350	107.357240	193.212330	169.231660
PVMAX	4	473.899680	307.153570	742.991360	560.897330	669.866340	484.847240
PVMIN		4.783637	−1.207139	251.407800	127.660670	98.924542	8.742991
CUMMIN		1.646740	−6.751520	24.420000	24.420000	24.420000	4.075000
EPDV		280.319920	146.801500	603.196480	435.559760	492.034400	322.048660
SD		198.837600	158.560910	182.260750	158.898120	248.677670	226.416470
PVMAX	5	526.163410	355.488160	918.702070	731.769470	789.534420	603.126400
PVMIN		−45.239343	−54.778475	218.976060	88.057907	56.838252	−38.800572
CUMMIN		−51.630520	−65.091040	−0.580000	−1.480000	−1.494200	−47.710000
EPDV		255.741270	132.754330	443.632620	281.785030	368.258320	207.152560
SD		124.438280	83.757279	79.660269	56.221810	138.129970	112.602890
PVMAX	6	408.272330	245.455340	553.917010	376.661560	536.834630	353.204440
PVMIN		41.442980	39.000561	270.475910	153.899810	127.647200	42.922918
CUMMIN		40.924000	37.588000	42.420000	42.420000	42.420000	41.860000

Standard Brands

		(SCENARIO) 1	2	3	4	5	6
EPDV		207.165070	147.339680	395.063540	323.792110	320.931820	246.054900
SD		125.181110	110.510440	121.406250	112.322870	153.398180	146.959410
PVMAX	1	366.126480	293.317940	617.876980	537.867020	508.987490	430.911070
PVMIN		14.199001	7.396861	136.556050	77.605779	63.970138	18.320627
CUMMIN		12.753641	3.462880	16.920000	16.920000	16.920000	15.360400
EPDV		181.095050	101.536950	378.196340	278.819490	308.830420	207.673040
SD		124.627740	101.093840	115.658460	102.147020	154.818350	142.056320
PVMAX	2	335.444340	234.263800	581.106260	470.263800	494.344880	383.968510
PVMIN		-25.079999	-31.070776	132.748150	54.770905	36.279975	-21.120646
CUMMIN		-28.853261	-37.251521	0.920000	0.920000	0.920000	-26.425000
EPDV		210.280740	120.928760	522.289740	419.336580	424.811770	315.563650
SD		198.630280	175.946980	210.225380	195.258990	252.455000	242.919070
PVMAX	3	456.936660	348.635460	911.137200	792.830380	717.394740	605.125670
PVMIN		-106.373130	-118.723020	82.843254	-7.263224	-30.101615	-97.679179
CUMMIN		-120.136860	-137.767140	-17.080000	-82.834800	-84.494201	-114.995400
EPDV		194.458690	114.900590	391.559980	292.183130	322.194050	221.036680
SD		124.627750	101.093840	115.658460	102.147020	154.818350	142.056320
PVMAX	4	348.807980	247.627430	594.469900	483.627440	507.708510	397.332150
PVMIN		-11.716363	-17.707139	146.111780	68.134542	49.643612	-7.757009
CUMMIN		-14.853260	-23.251520	7.920000	7.920000	7.920000	-12.425000
EPDV		200.066190	115.242360	464.660090	362.388680	377.400280	271.802910
SD		161.970160	138.843200	168.237710	153.842040	210.515690	199.504560
PVMAX	5	401.071700	295.962020	770.180600	654.499570	627.376590	515.611310
PVMIN		-61.739343	-71.278475	113.680040	28.531775	7.557322	-55.300572
CUMMIN		-68.130520	-81.591040	-17.080000	-34.480000	-34.494200	-64.209999
EPDV		175.487550	101.195180	305.096230	208.613950	253.624200	156.906810
SD		87.356640	63.577345	63.687723	50.586615	99.393394	84.988533
PVMAX	6	283.180620	185.929210	405.395550	299.391670	374.676800	265.689350
PVMIN		24.942981	22.500561	165.179890	94.373672	78.366266	26.422918
CUMMIN		24.424000	21.088000	25.920000	25.920000	25.920000	25.360000

(STRATEGY)

Appendix B. Summary of Considerations in Predicting Individual Firm Decisions

American Maize. This company is committed to the corn milling industry because of long participation and the background of top management. It cannot withstand very large negative cumulative cash flows, but it will want to participate in the HFCS market. American Maize is one of the older CWM companies that had been damaged by the entry into CWM of Cargill and Archer-Daniels-Midland, both of which entered with large, efficient operations.

Anheuser-Busch. Primarily a beer company, AB developed its own enzyme technology for HFCS production. It will enter if the opportunity is right. The financial resources are large enough to absorb risk, but AB is far from committed to CWM. The AB corn milling operation reports to a Busch executive also responsible for the St. Louis Cardinals and Busch Gardens, other AB operations. Busch has been in corn milling primarily as a by-product of technological capability drawn from its brewing operations.

Archer-Daniels-Midland. A closely held company with large financial resources, ADM had successfully entered CWM in 1970–71. The company's experience is in agricultural commodities, and it is used to low margins and wide earnings swings, and to surviving through competing with large, highly efficient facilities. ADM can absorb risk and is known as a risk taking company. Short-run dips in stock prices are of less concern to ADM than to less closely held firms. ADM was likely to invest heavily, as it had in basic CWM in 1970–71.

Cargill. Cargill is an extremely large, privately held, very successful grain trading company that was diversifying into other commodity products much like ADM. Cargill has much in common with ADM: it is a risk taker, it has significant financial resources, it is experienced with cyclical commodities, and it is used to competing on cost and scale. Our feeling is that Cargill is slightly more conservative in taking risks than ADM.

CPC International. Long the historical leader in CWM, CPC had relinquished a substantial share of the market by 1972. Managerial and financial resources had been devoted to a successful program of international expansion and diversification into consumer products. CPC had the financial resources to compete vigorously in HFCS, was very conservatively managed, and was attempting to achieve steady growth in sales and earnings. In 1972, HFCS was likely to appear too risky to justify a major commitment of resources. CPC therefore would enter tentatively and in a small way.

Grain Processing. This is a privately held company with a history similar to that of ADM and Cargill. We know very little about GP, and hence their behavior is hard to predict. They entered CWM in the mid-sixties before Cargill and ADM. That entry seemed less aggressive than the later moves by Cargill and ADM.

Hubinger. Hubinger is a small old-line corn wet miller. It is totally dependent on CWM and in financial difficulty as a result of the price wars accompanying ADM's entry into CWM in 1970–71. Hubinger will want to participate in HFCS, but with limited financial resources could not mount a major effort. At most they would be likely to convert. As a matter of history the H. J. Heinz Company bought Hubinger in 1975 (having failed in a bid to acquire Staley), and with Heinz's considerable resources, Hubinger did move into HFCS in 1976.

National Starch. This company is a relatively small, enormously successful specialty starch and adhesives company whose strategy consists of R&D and product differentiation. NS has consistently avoided undifferentiated commodities and the need for high volume, low cost operations by producing only specialty starches among CWM products. NS is well managed and would not regard HFCS as either a threat or an appropriate opportunity. It was the least vulnerable of any firm to excess capacity in the traditional HFCS markets.

Pennick & Ford. A relatively small old-line CWM company, P&F, like Hubinger, was hurt by the ADM entry. P&F was purchased by R. J Reynolds in the mid-1960s and then sold under Federal Trade Commission pressure to VWR Corporation. VWR was experiencing profitability problems, and the P&F operation was losing money in 1972. P&F could want to play the HFCS game, but lacked the financial resources for a large, risky commitment and perhaps even for a modest commitment.

Staley. Staley was a major participant in CWM and the only firm to license the HFCS technology from Standard Brands before 1972. In 1972, Staley had 200 million pounds of HFCS capacity on-stream, about the same as Standard Brands. Staley is heavily committed to HFCS and possesses significant financial resources. But a very large investment in HFCS may strain Staley's financial situation depending upon how the HFCS market develops.

Standard Brands. SB is a diversified consumer food products company. It purchased Japanese technology for HFCS production and pioneered the commercial introduction of HFCS in the United States. SB had significant financial resources and is not heavily dependent on CWM. It like CPC had turned its attention away from corn wet milling into other businesses in recent years and offered to license the technology to any firm that wanted it. Its initial strategy seemed to be to encourage develop-

ment of the HFCS market while aggressively leading the development. Thus, it will probably invest, but not attempt to preempt the market.

As a matter of historical record, Amstar, the largest sugar refiner in the United States, also entered HFCS, to hedge against the obvious threat HFCS presented to the traditional sugar markets. It was believed, and still is to some extent, that HFCS is, in the long run, at least as inexpensive a liquid sweetener as sugar and is probably lower in cost than sugar.

Notes

1. All data used in this paper are taken from Michael E. Porter and Margaret Lawrence, *Note on the Corn Wet Milling Industry in 1972* (Intercollegiate Case Clearinghouse, Boston, 1978, Case 1-378-186, and *Note on the Corn Wet Milling Industry, 1973–1977* (Intercollegiate Case Clearinghouse, Boston, 1978, Case 1-378-206).

2. The industry also produced other products, including dextrose and dextrins. They are not nearly so important as starch and corn syrup, and are omitted from the discussion for simplicity.

3. This Nash equilibrium concept has been criticized in static models on the grounds that it involves mistaken assumptions about rivals' behavior. The point there is that an oligopoly game is played repeatedly or continuously. This creates a situation in which learning about rivals' behavior can occur and behavior can adapt. However, the capacity expansion game is played once. The issue of whether to assume firms will continue doing what they are doing now (a poor assumption in the pricing problem) does not arise here. In the capacity expansion situation, the problem for the firm is to avoid errors about rivals' behavior. That, we argue, involves finding a pairing of individual firm choices and aggregate outcomes that is internally consistent.

4. All demand figures are taken from United States Department of Agriculture *Sugar and Sweetener Reports*.

5. More precisely, this involves making the following approximation: Our interest will be in the mean and variance of the present value of net cash flows. Since the cash flow in period t depends on sugar price in period t, the expected value or mean of the present value is not affected by our implicit assumption that sugar prices are perfectly correlated over time. The variance, however, is affected. Let $Vt(pt)$ be the discounted present value of the derivation of the cash flow in period t, as a function of the sugar price in period t. The variance of the present value of net cash flows is

$$V = \sum_{\tau,t=1}^{T} E(Vt(pt)V\tau(p\tau)).$$

Taking a linear approximation $Vt(pt) = Vt'(\bar{p})(pt - \bar{p})$,

$$V = \sum_{\tau,t=1}^{T} Vt'(\bar{p})V\tau'(\bar{p})\,\mathrm{cov}\,(pt,p\tau).$$

What we did is set $pt = p$, a random variable. Thus, our calculated variance is

$$\hat{V} = \sum_{\tau,t=1}^{T} Vt'(\bar{p})V\tau'(\bar{p})\,\mathrm{var}\,(p).$$

Letting $s\tau t$ be the correlation coefficient for pt and $p\tau$,

$$V = \sum_{s,t=1}^{T} Vt'(\bar{p})V\tau'(\bar{p})\,st\tau\,\mathrm{var}\,(p).$$

Thus, $\hat{V}$, the measure we used, overstates the variance of the present value of cash flows by an amount that depends inversely on the closeness of the serial correlation $\hat{V}$ and V. With no serial correlation, all the terms in V with $t \neq \tau$ are zero. With more time and a larger budget one would want to estimate an autoregressive model for sugar prices and use that in calculating V. But that was not done here. The result is an overstatement of the variance of present value of net cash flows.

6. Making capacity expansion adapt to demand is in lieu of a full dynamic programming treatment in which one would work backward from future to present decisions.

7. We have ignored for simplicity the option of adding corn syrup and HFCS refining capacity to existing grind capacity.

8. We recall that the specific assumptions about HFCS demand are as follows: (*a*) In the long run, liquid sugar and HFCS are close substitutes, and as a result HFCS will be priced close to sugar. (*b*) Demand for HFCS is also a function of industry capacity. (*c*) In the short and medium term, HFCS demand may be substantially below its long-run equilibrium level, because of changeover costs and possible taste effects for bottlers.

9. *Business Week*, 15 November 1976.

10. For a listing of the announced capacity decisions, see "Note on the Corn Wet Milling Industry, 1973–1977," Harvard Business School, Case 1-376-206.

11. One might interpret the preemptive investment prescription in a different way. Admitting that uncertainty may make such a strategy unacceptably risky to a single firm, one could use it as a screening device: put resources preemptively into markets where the risks are not imprudently high. Or more bluntly, do not play risky competitive games. Whether that is good advice depends upon the menu of investment opportunities that are open to the firm. It has the luxury of choosing among low risk, high return investments; few would argue that it should accept the risks involved in markets like HFCS, but not all firms have this option.

12. The model takes expectations about demand as exogenous. Expectations about capacity expansion and competitor behavior are endogenous, and emerge from the equilibrium analysis.

13. This problem of large numbers of equilibria is reminiscent of the oligopoly problem in the mature industry, where reasonable concepts of equilibrium do not delimit the outcomes sufficiently for predictive purposes.

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Comment

Sidney G. Winter

There are clearly good reasons to regard the Porter and Spence paper as being in a different genre from the others presented at this conference—for example, the others say very little about corn syrup.

At a higher level of abstraction also, the paper has a unique orientation. In my comments, I want to view the paper in perspective from a high level of theoretical generality, and in so doing to emphasize some of its distinctive features more than the authors themselves have done. The "perspective" I offer is not a critical one, for I find myself much in sympathy with the sort of inquiry that Porter and Spence have undertaken. Their willingness to plunge into the detail of a specific industry in a specific historical setting and to organize that detail in a coherent theoretical framework seems to me quite laudable. The resulting analysis illuminates not merely the specific situation studied, but also the broad and fundamental problem of the role of prices and markets in coordinating activity. On the other hand, I am skeptical about some details of their approach. In the final section of my comment, I suggest an alternative view of how oligopolists might succeed in coordinating their investment behavior in the sort of situation they describe.

In his 1968 presidential address to the Econometric Society, F. H. Hahn reviewed some basic problems in analysis of the adjustment dynamics of market systems. He closed with an elegant and concise statement of our central theoretical task: "The most intellectually exciting question of our subject remains: is it true that the pursuit of private interest produces not chaos but coherence, and if so, how is it done?" (Hahn 1970, p. 12). To study economic dynamics is, of course, to appreciate the particular importance of the query, *How is it done*? The result of Hahn's survey was a rather gloomy appraisal of the progress that economic theorists had made in understanding the mechanism of the "invisible hand": "I see no support for the view that any of the traditional methods of response of various agents to their economic environment makes the 'hand' perform as it is often taken to perform." (Hahn 1970, p. 1).

Although there have been many important advances in economic theory since Hahn's address, a similar survey today would no doubt reach much the same conclusion. Progress toward understanding the active coordinating function of the market mechanism has been minimal. This is a consequence of the overwhelmingly dominant role of equilibrium analysis in the research method of most economic theorists. As practiced by economists, equilibrium analysis involves the application of consistency tests to limit the range of situations that are regarded as actually realizable in economic life. The great power of the method lies precisely

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in the fact that it obviates the need to study the complicated and probably situation-specific dynamic processes by which "inconsistencies" in the system are identified and eliminated. However, it is hardly surprising that economists remain uninformed about the answers to questions they have chosen to suppress. The question, *How is it done*? remains largely unanswered because it remains largely unexplored.

That equilibrium analysis, as usually practiced, fails to illuminate disequilibrium processes is inherent in the logic of the method. That the failure is an important one—perhaps so important as ultimately to force the sacrifice of the great simplifications the method yields—is a feature of economic reality. More specifically, the importance of the failure can be attributed to the following four features of reality, taken singly and in combination.

—Futures markets and contingent markets exist only in negligible proportion to the scope envisaged for these institutional devices in abstract models of efficient intertemporal allocation under uncertainty.
—The institutional reality does not include a *tatônnement*; more broadly, it includes no device for systematically checking the consistency of tentative plans formulated by a large fraction of economic actors *before* actual implementation of those plans has begun.
—The existence of specialized producers' durables and the cost conditions characteristic of processes of information acquisition, transfer, and storage contribute an important degree of irreversibility to many economic decisions; i.e., with all prices held constant there are large present value sacrifices involved in reverting to an initial state after having taken certain sorts of actions.
—Technological change continually generates new, imperfectly anticipated allocational possibilities, and at the same time destroys the viability of old allocations; more broadly, such processes of long-term historical change as population growth, industrialization, resource depletion, waste accumulation, and naturally occurring climatic change all combine with advancing technology to present a continually novel context for all economic choice.

But for the first two considerations, the market mechanism would in fact be the sort of planning system to which economists often compare it. Currently functioning markets would signal the future consequences of proposed current action, conditioned by the proposed current actions of others. But in fact, it is overwhelmingly the case that it is steps actually *taken* by each actor that impinge on the others, not steps *contemplated*. And the implications of steps actually taken may remain latent and obscured for a long time, before they affect prices in a functioning market. Such a system does not necessarily produce "chaos," but to

represent it as a system that checks plans for mutual consistency is to employ a loose and misleading metaphor.

Were it not for the third consideration, the consequences of imperfect coordination would be ephemeral, and the distinction between consistency testing of plans and consistency testing of actual actions would evaporate. As inconsistencies appeared, revealing some past choices as mistaken, there would be quick reversals and redirections of action. The stability properties of such a multiactor, frictionless quest for a consistent solution are problematic, but at least the social learning process would not be complicated and slowed by the accumulating, slowly depreciating "debris of the actual groping process" (Hahn 1970, p. 4). As it is, the actor who has made an economically irreversible mistake has presumably learned something about the problem he faced, but he now faces a new problem. And the actor who has somehow stumbled on the (or "an") equilibrium action will fail to find corroboration of his choice as the durable consequences of the mistaken choices of others shape his environment.

Finally, the reality of nonrepetitive historical change mocks the equilibrium theorist's last-resort comforting thought, the proposition that, if the problem stands still, the social learning process will surely find the right answer to it. Given enough time, even slow learners making slowly depreciating mistakes should be able to grope their way to a solution. Again, acceptance of this hypothetical proposition is qualified by concerns about the stability of the adjustment process; also, information cost considerations provide reason to doubt the supposition that the accumulation of sufficient experience is the only requisite of perfect learning. But the important point is that these sorts of questions arise only in models. In reality, the problem is not standing still at all.

I should emphasize that the foregoing considerations do not directly imply any judgment on the merits of market mechanisms and the pursuit of private interest as against any concrete organizational alternative for dealing with the social coordination problem. The invisible hand has many strengths, and in many contexts those strengths may confer a decisive superiority relative to other arrangements. Rather, the judgment is about the adequacy of equilibrium analysis in the neo-Walrasian tradition, and it is one of skepticism about the ability of that sort of analysis to reveal the true character of the institutional arrangements it purports to analyze. The insights of Hayek (1948) and Schumpeter (1950), though admittedly undeveloped by contemporary standards, may have a more direct bearing on the "most intellectually exciting question of our subject" than the modern theorist's storehouse full of existence and optimality results.

Now consider, from this point of view, the situation in the corn wet milling industry that Porter and Spence describe. A technological advance—the development of a commercially viable production method for

high fructose corn syrup—faced the firms of the industry with a novel decision context. The market for their products had expanded in a relatively *unanticipated and discontinuous* manner, an aspect of the situation underemphasized by the title of the Porter and Spence paper. It was clear that the new product represented a profit opportunity, but the size of the market would ultimately depend on the degree to which HFCS could displace sugar in various applications. Also, and fundamentally, it was not at all clear to whom the profit opportunity "belonged." If all firms were to respond aggressively by adding new capacity to produce HFCS, they might all regret it—even in the event of strong demand. On the other hand, very timid responses all around would mean high profits per unit, but low total profit. Thus, from the point of view of industry profitability, and of course also from a social welfare point of view, a significant coordination problem existed. By making investment decisions without a proper allowance for the contemporaneous actions of others, firms could easily sacrifice profits and waste resources. Overresponse in particular posed the threat of prolonged overcapacity not just in HFCS, but in all markets involving the same upstream processes. (The standard of a "proper allowance" for the actions of others depends of course on whether one is concerned about profits sacrificed or resources wasted.)

An organized futures market in HFCS, extending several years into the future, could have performed a valuable social role. The commodity itself was sufficiently standardized to present no serious obstacles to such an arrangement. Although producers might have been reluctant to enter into unconditional contracts to deliver a commodity they had never produced before, a more flexible standard contract could have been devised to shift a part of the production risk to the buyer. An active market in such futures contracts would have registered in price movements the developing information on the relationship of capacity and demand. Producers could have guided their capacity decisions accordingly. Soft-drink manufacturers and other potential HFCS buyers would have faced a clear measure of their incentive to convert from sugar to HFCS, and could have laid off to speculators most of the risk associated with their own investments in learning about the new sweetener. Of course, a functioning futures market is not a *tatônnement* on intertemporal prices; there is more to coordination than aggregating available information about actions taken. But there was no futures market, let alone a *tatônnement*. Perhaps there is a generalizable lesson here, a pessimistic principle that says that economic change rarely goes forward in an institutional context well suited for its guidance and control. Rather, the lag of institutional adaptations behind the need for them is a part of the problem of change.

It seems unlikely that the investment response of the corn wet milling industry to the HFCS opportunity came close to some plausible standard of ex ante optimality, but of course such questions are almost as difficult

to judge in retrospect as in prospect. From the Porter and Spence account, it does seem clear that the investment choices of the industry as a whole did at least display a good deal of coherence. Viewed in a Schumpeterian perspective, their case study might even be appraised as a typical success story for the market mechanism, only slightly qualified by reference to the generalized (and perhaps unavoidable) failure to appreciate the depths to which the sugar price might sink. In the neo-Walrasian framework, however, the story hardly fits at all. The market mechanisms analyzed by Porter and Spence operate on different principles and perform different functions than the stylized market mechanisms of general equilibrium theory.

Starkly put, their explanation of how "coherence" was achieved and "chaos" avoided is that all firms computed the Cournot solution to the HFCS investment problem and acted accordingly. The Cournot model involved has a number of sophisticated elements, including demand uncertainty, mutual recognition of differentiating features of the oligopolistic rivals, and a range of qualitatively different investment options. But the basic coordinating force is the assumed general principle that the course of industry development anticipated by each individual firm is one it expects would be realized if it were generally anticipated. As the authors rightly remark, the acceptability of the Cournot equilibrium analysis in the context of the single-move investment game is considerably higher than it is in the more familiar context of output determination. It is important to emphasize, also, that they resort to equilibrium analysis not merely as a convenient theoretical device, but as a plausible abstraction of actual decision process in the industry—an answer to the question, *How is it done*?"

The most fundamental contrast between their analysis and neo-Walrasian equilibrium theory involves the informational role of prices. Prices are not sustaining equilibrium; they are signaling disequilibrium. The steps taken in response to disequilibrium are coordinated, imperfectly, by a variety of *nonprice* information flows and by actors' anticipating each other's behavior. The results of those steps are only tardily reflected in price movements, when it is too late to reconsider the steps but not to adapt to the new disequilibrium that they have produced. The players in the game need to know as much as possible about the details of each other's situation. In the Porter and Spence account *all* firms are performing the functions of the commissar for corn wet milling—a perspective sharply different not only from neo-Walrasian theory, but also from the Hayekian picture of the information processing economies of the market.

A number of features of the specific situation in the corn wet milling industry contribute to the plausibility of the explanation offered for the degree of coordination achieved.

—The situation involves a relatively short list of actors, all of whom are known to each other. A flood of *de novo* entry into the industry, from unidentified sources, is apparently not a sufficiently likely prospect to be taken into consideration. The firms involved evidently think, with reason, that they collectively "own" the new profit opportunity, although it is not immediately obvious what the ownership shares are.
—The actors can draw on a large fund of shared information about each other. The scale of past participation and previously revealed attitudes toward risks are particularly important indicators of likely future behavior. Prediction efforts based on this sort of information are not severely complicated by product differentiation or by secret development efforts proceeding simultaneously in several laboratories.
—Similarly, the actors share a fund of information about the demand side of the picture, derived from contacts with potential buyers and public sources. Again, the absence of product differentiation simplifies the problem of drawing inferences from this sort of information.
—Security analysts act as independent arbiters of expectations regarding the future prospects of the industry as a whole. Provided that the expectation thus certified is reasonably accurate and consistent with the reactions to it, this can make for improved coordination; otherwise, it can mean the investing firms are all wrong together.
—Firms communicate with each other through public statements, financial reports, and observable actions taken.
—Risk aversion and perhaps financial constraints limit recourse to preemptive strategies. These considerations operate to restrain and stabilize the aggregate industry investment to a degree that depends on the size of the contemplated investment opportunity relative to the size of the investing firms.

Any attempt to assess the generality of the mechanisms described, or to apply similar logic to other cases, might well focus on the extent to which these features of the original case are replicated.

I close these comments with a sketch of an alternative model of investment coordination in the situation studied by Porter and Spence, a model that seems to me to have somewhat greater behavioral plausibility than the Cournot-style computation they impute to the firms. In this alternative view, firms focus initially not on the capacity expansion path of the industry but on the full cost of production (including target return) of HFCS. This calculation would determine a price level just low enough to eliminate incentives for further additions to capacity. Consideration of the uncertain demand for HFCS would follow, resulting in a best estimate of the capacity likely to be ultimately installed, perhaps with a qualifying indication of high and low values. The first-cut answer to the question how the opportunity would be shared in the industry would be provided

by reference to prevailing market shares in corn syrup. This preliminary estimate would then be modified by each individual firm according to its view of the special attributes and circumstances—including financial constraints, atypical cost conditions, and attitudes toward risk—of its rivals and itself. Such modifications would be constrained by the technical indivisibility of investment and would not be likely to go outside the range of plus or minus one MES plant. In finally carrying out its own plan, each firm would view itself as laying claim to its appropriate, historically based share of the new industry opportunity.

Like the Porter and Spence scheme, this alternative one has the central property that it would not, in many circumstances, produce "chaos" in the sense of a vast disproportion between the aggregate investment undertaken and the estimated size of the aggregate opportunity. Also like their scheme, there is a list of considerations that are highly relevant to its efficacy as a coordination device, but there is only a partial overlap between the two lists. In particular, the role played in their model by risk aversion is here played by the assumption that firms roughly scale their ambitions in the new market to their historical shares in the old one. This change amounts to a more explicit recognition of the fact that what the firms need to roughly coordinate their behavior is a Schelling (1960) focal point. Although the carrying out of the same Cournot equilibrium calculation by all parties might well provide the focal point if economic theorists were doing the calculating, I suspect that the historical shares approach would more readily come to the mind of the businessman.

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