EVOLVING COMPUTER PERFORMANCE 1963-1967

by KENNETH E. KNIGHT

"Changes in Computer Performance" (DATAMATION, Sept. 1966) traced the developments in high speed digital computers from the Harvard Mark I in 1944 through the early months of 1963. In this second article we will examine 93 computer systems introduced between 1963 and 1967.

We again consider two aspects of computer performance: 1) computing power, indicated by the number of standard operations performed per second (P); 2) cost of the computing equipment, which equals the number of seconds of system operations per dollar of equipment cost (C).

Computing power (P) evaluates the rate at which the system performs information processing, the number of operations performed per second. Two machines solve a specific problem with different internal operations because of their individual equipment features. (P) will, therefore, describe operations of equivalent problem solving value to provide the desired measure of a computer's performance.

The equations to calculate computing power are identical to the ones described in the Sept. 1966, DATAMATION article, pp. 40-42. These were constructed by means of a careful analysis of the internal operations of each computer and allow us to calculate the relative performance of that computer for an average problem for scientific (and commercial) computation.[1] Using the same procedure we carried out the calculations for 93 computers introduced from 1963 through 1967 (Table 1).

a statistical averaging technique

The procedures used to calculate the computing power (P) and computing cost (C) represent a statistical averaging technique. The calculated numbers for a particular machine should not be taken as the "measure" for that particular machine. In making the calculations we used only one configuration for our average set of problems. The configuration selected was the one that was representative of the early systems. It should be emphasized that no attempt was made to optimize either throughput (number of calculations per second) or cost (number of calculations per dollar) for the machine.

The calculations of P (operations/second) and C (seconds/$ rental) are intended to provide over-all comparisons between machines of various sizes and between machines introduced in different years. From this data we determine the advances in computing power over time and investigate the differences between small and large computers (Grosch's Law). Because of the averaging technique used to calculate (P) and (C) our data do not provide direct comparisons between two machines for the specific set of user needs.

performance improvements 1963-1966

Data for commercial and scientific computation (Table 1) are plotted in Figs. 1 and 2 *(p. 33-34)*. As in the earlier article a regression technique has been used to describe the changes in computer performance from year to year and also to compare the computer performance per dollar of computer cost. The equation fitted is the same as the one used for the period 1950-1962:

$$\ln(C) = a_0 + a_1 \ln(P) + B_1 S_1 + B_2 S_2 + B_3 S_3 + B_4 S_4$$
(Equation 1)

In this equation the a's and B's represent the regression coefficients to be determined by the least squares analysis. The S_1, S_2, S_3 and S_4 represent dummy variables (or shift parameters) for the different years considered (1963-1966). For the regression we will include 1962 as the base year. We will also consider all the systems from 1963-1966 in the regression analysis.

The result of the regression calculation using all 111 computers introduced between 1962 and 1966 are as follows:

For scientific computation: [2]

$$\text{Ln}(C) = +6.823 - .322 \ln(P) \quad \text{(Equation 2)}$$

+0.000 (1962)
+0.272 (1963)
+0.415 (1964)
+0.822 (1965)
+0.988 (1966)

For commercial computation: [2]

$$\text{Ln}(C) = +7.441 - .404 \ln(P) \quad \text{(Equation 3)}$$

+0.000 (1962)
+0.385 (1963)
+0.723 (1964)
+1.186 (1965)
+1.550 (1966)

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[1] The performance capability of each computer was determined for a typical mix of scientific/research problems and for an average mix of commercial/industrial problems.

[2] For both Equations 2 and 3 the adjusted (R^2) was over .80 and the a_1's, and B's were all statistically significant, different from zero at greater than the .01 level.

The plots of Equations 2 and 3 are shown in Figures 1 and 2.[3, 4] We see that the most striking observation once again is the rapid advance in computer performance. For scientific computation the average improvement in performance over the previous year, holding cost constant, is determined by the shift in the technology curve between 1963-1966. The measured shift is about 115% increase per year in computer capability for equal cost. The result shows that the rate of equipment improvement is even greater than that experienced in the years 1950 through 1962, an average of 81% per year. For commercial computation we find an average of about 160% per year, 1963 through 1966, against the earlier 87% for the years 1950 through 1962. As shown in Fig. 3 *(p. 34)*, we find that there has been a steady advance in computer performance capability each year 1963-1966, that is, each of the four years had a significant improvement in both scientific and commercial computation capability. *(Continued p. 35)*

Table 1

COMPUTING SYSTEMS

Computer No.	Name	Date Introduced	Scientific P (Ops/Sec)	Commercial P (Ops/Sec)	C (Sec/$)
219	IBM 7040	4/63	21,420	9,079	44.54
220	IBM 7044	7/63	67,660	23,420	23.98
221	RCA 601	1/63	68,690	58,880	13.86
222	Honeywell 1800	11/63	110,600	57,750	17.81
223	Philco 1000	6/63	6,811	10,440	65.63
224	Philco 2000-212	2/63	369,800	84,230	9.169
225	Librascope L 3055	12/63	114,000	30,620	10.39
226	H.W.Electronics 15K	2/63	119.6	50.98	1,247
227	GE 215	6/63	5,246	6,924	89.07
228	DDP-24	6/63	580.4	632.7	124.7
229	CDC 3600	6/63	459,065	156,375	12.47
230	UNIVAC 1050	9/63	12,028	19,675	113.4
231	UNIVAC 1004	9/63	97.12	1,473	415.7
232	PDP-5	10/63	6,338	12,519	311.8
233	IBM 1460	10/63	1,611	7,200	69.28
234	IBM 1440	11/63	1,412	5,559	183.40
235	Honeywell 1400	12/63	1,770	6,821	41.57
236	ASI 2100	12/63	24,628	10,241	178.2
237	SDS-93C0	12/63	43,876	10,646	89.07
238	Burroughs 273	1/64	714.6	3,467	87.82
239	GE-235	1/64	28,557	22,244	51.96
240	IBM 7010	1/64	5,729	11,537	31.18
241	Burroughs B 160-180	4/64	295.5	1,599	145
242	CDC 160G	4/64	54,065	20,278	89.07
243	IBM 7094 II	4/64	217,108	95,146	8.20
244	CDC 3200	5/64	195,256	87,510	51.96
245	GE 415	5/64	7,472	15,668	77.94
246	UNIVAC 1004 II, III	6/64	79.16	1,878	283.4
247	SDS-930	6/64	73,181	21,035	103.9
248	GE 425	6/64	11,485	22,160	62.35
249	GE 205	7/64	1,775	6,188	311.8
250	Honeywell 200	7/64	1,148	7,027	103.9
251	RCA 3301	7/64	126,761	58,359	44.54
252	PDP-6	7/64	46,359	32,803	51.96
253	CDC 6600	9/64	7,021,619	4,091,293	8.31
254	UNIVAC 418	9/64	58,767	166,564	62.35
255	NCR 315-100	11/64	6,164	17,251	155.9
256	GE 635	11/64	338,958	253,898	11.34
257	CDC 3400	11/64	269,859	157,202	29.69
258	Burroughs B5500	11/64	376,275	544,201	20.78
259	SDS 925	2/65	92,692	150,102	155.9
260	SDS 92	2/65	19,140	79,065	239.8
261	CDC 3100	2/65	118,462	74,391	77.94
262	ASI 6020	3/65	28,160	13,161	178.1
263	DDP-224	3/65	52,330	81,492	103.9
264	DDP-116	4/65	2,176	4,023	677.7

COMPUTING SYSTEMS

Computer No.	Name	Date Introduced	Scientific P (Ops/Sec)	Commercial P (Ops/Sec)	C (Sec/$)
265	GE 625	4/65	224,374	118,154	15.20
266	PDP-8	4/65	1,768	990.5	230.9
267	PDP-7	4/65	68,497	29,571	103.9
268	IBM 360/40	5/65	33,438	50,073	54.08
269	IBM 360/30	5/65	7,942	17,104	72.88
270	NCR 315 RMC	7/65	132,060	153,770	62.35
271	UNIVAC 1108 II	8/65	2,075,181	2,088,142	10.39
272	GE 435	8/65	24,803	56,623	41.57
273	IBM 360/50	9/65	187,488	148,967	27.47
274	IBM 1130	9/65	16.38	56.76	692.8
275	NCR 590	9/65	4.288	21.76	519.6
276	ASI 6240	10/65	33,177	13,232	155.9
277	UNIVAC 491 & 492	10/65	4,929	48,490	36.68
278	RCA Spectra 70/15	10/65	1,837	16,586	164.1
279	Raytheon 520	10/65	29,118	13,427	207.8
280	IBM 360/75	11/65	3,560,854	1,437,806	11.81
281	Honeywell 2200	12/65	12,222	14,332	77.94
282	CDC 3800	12/65	690,510	150,726	12.47
283	RCA Spectra 70/25	12/65	4,818	36,366	103.9
284	Friden 6010	1/66	1.66	48.66	1,039
285	CDC 6400	1/66	696,086	193,785	12.47
286	DDP-124	1/66	5,812	7,618	249.4
287	Honeywell 1200	1/66	2,130	10,907	115.5
288	IBM 360/20	1/66	1,932	4,497	239.8
289	UNIVAC 1005 II, III	2/66	88.25	1,677	259.8
290	UNIVAC 1005 I	2/66	71.73	1,186	366.8
291	Honeywell 120	2/66	2,108	9,526	190
292	IBM 360/65	3/66	1,385,573	809,738	13.86
293	UNIVAC 494	3/66	1,291,740	1,527,140	24.94
294	SDS 940	4/66	289,444	301,365	34.64
295	RCA Spectra 70/55	7/66	1,341,132	1,224,010	19.48
296	RCA Spectra 70/45	7/66	211,610	290,493	41.57
297	RCA Spectra 70/35	7/66	61,186	126,391	77.94
298	Philco 200-213	10/66	6,251,118	4,307,061	7.793
299	IBM 360/44	10/66	1,025,941	858,520	62.35
300	Honeywell 4200	5/67	45,569	32,270	31.18
301	SDS Sigma 7	12/66	894,566	554,280	41.57
302	PDP-8/S	9/66	1,595	8,546	1247.
303	PDP-9	12/66	107,672	352,534	1247.
304	SDS Sigma 2	1/67	118,152	101,079	155.8
305	Burroughs B 2500	2/67	22,153	28,791	124.7
306	Burroughs B 3500	5/67	154,842	130,251	69.31
307	UNIVAC 9300	6/67	4,350	18,424	138.6
308	UNIVAC 9200	6/67	1,592	7,458	415.7
309	Burroughs B 6500	2/67	3,127,266	2,755,760	15.59
310	CDC 3500	9/67	1,086,342	1,021,365	29.69

[3] The technology curves shown in Figures 1 and 2 are not comparable with those in the September, 1966 *Datamation* article. The curves shown in the current figures were calculated using all the general purpose computers introduced in the period 1962-1966. The earlier article used a procedure that eliminated some of the systems that were technologically inferior, those that fell far below and to the left of the technology line.

[4] Note that the slopes of the technology curves shown in the *Datamation*, September 1966 article, 1952-1962, were steeper than the current curves — 1962-1966. This results in the appearance that the base 1962 curves in Figs. 1 and 2 have been rotated and therefore they are not identical to the one shown in the earlier article; that is:

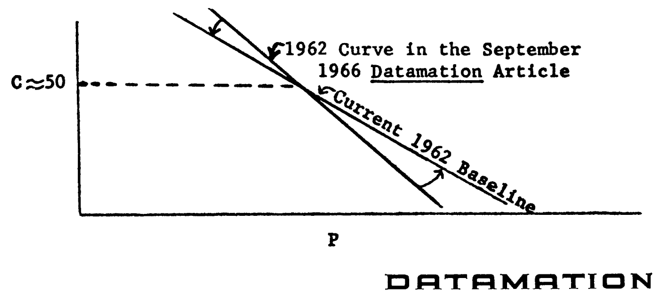


Fig. 1 Plot of Equation 2: regression calculation for scientific computation

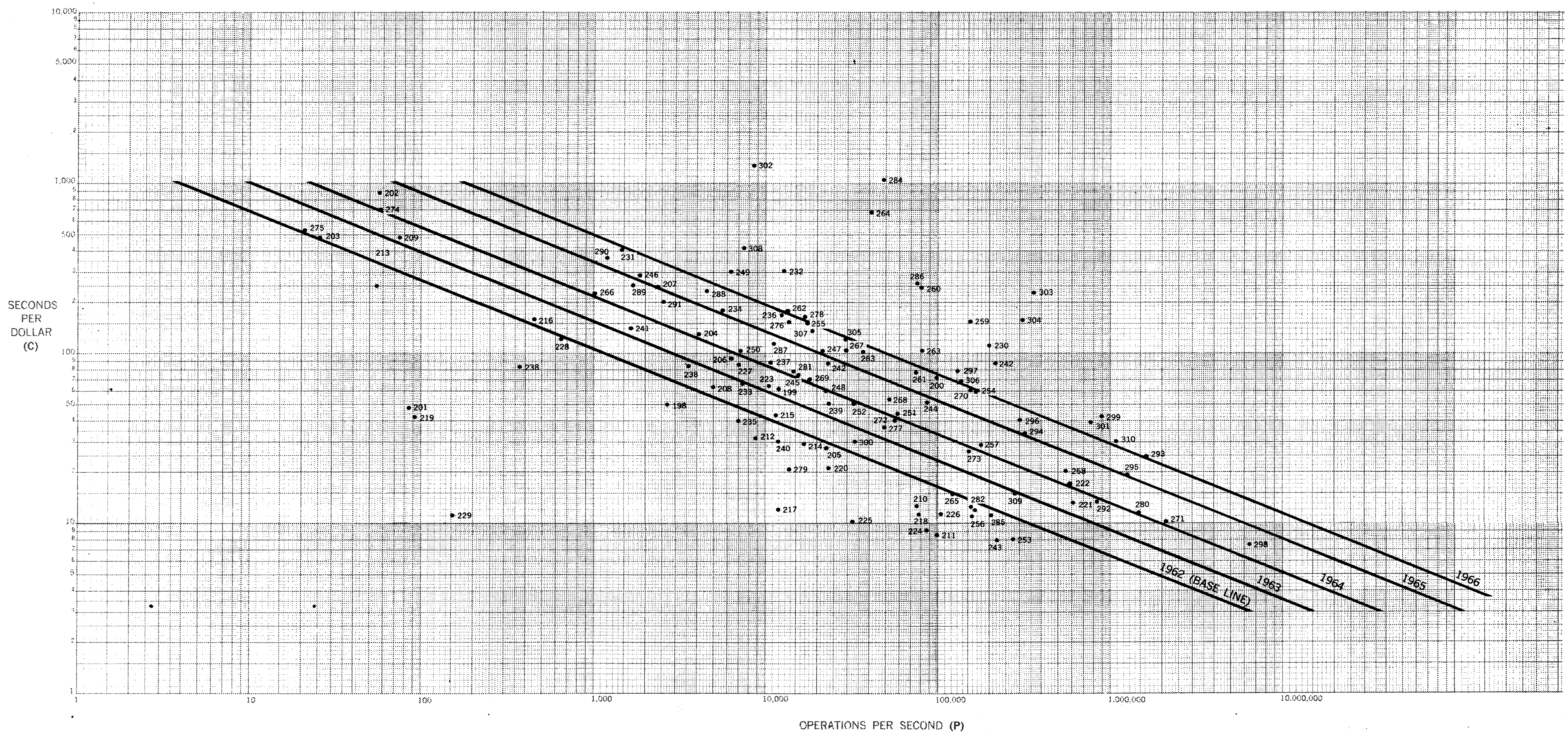
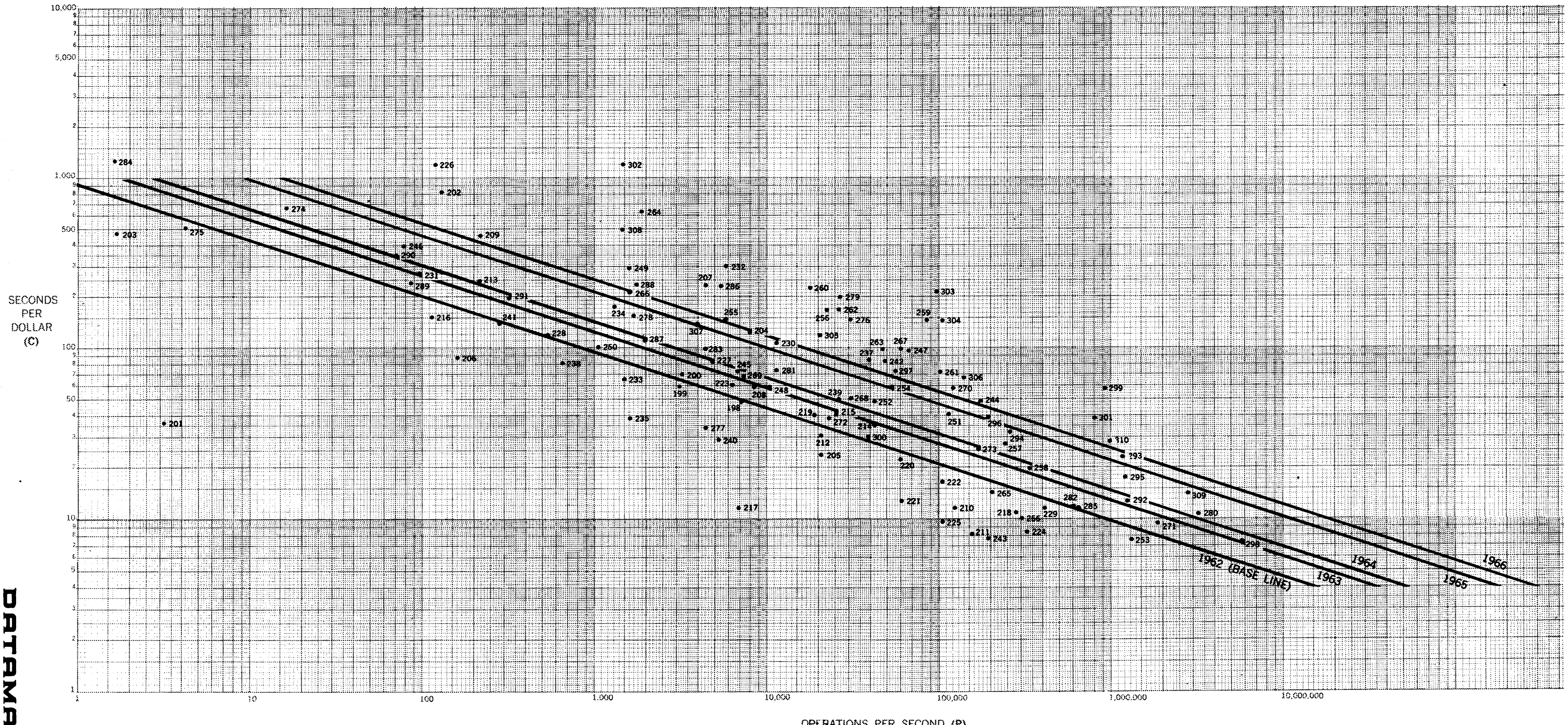


Fig. 2 Plot of Equation 3: regression calculation for commercial computation



grosch's law upheld

From our regression equation we obtain the new calculation of the economies of scale, Grosch's Law, for the years 1962 through 1966. Rewriting Equation 1 we get:

$$(C) = K \quad (P)^{a_1}$$

$$(Sec/Cost) = K \, (Power/_{sec})^{a_1}$$

$$\left(\frac{1}{cost}\right) = K \, (Power)^{a_1}$$

$$(cost)^{-1} = K \, (Power)^{a_1}$$

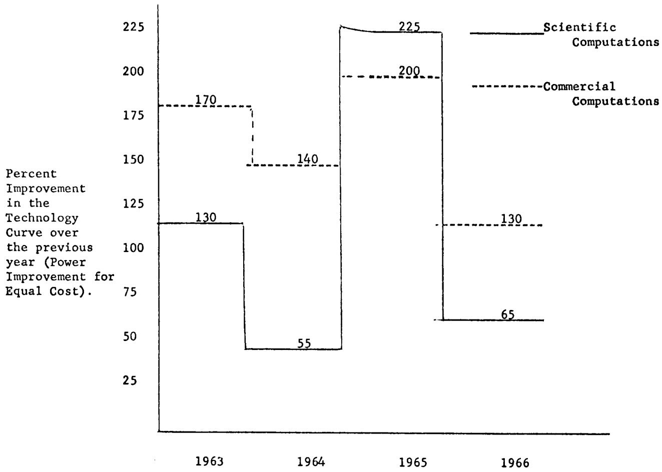
$$(cost) = K \, (Power)^{-a_1}$$

K is a constant which represents a combination of a_0 and the yearly shift parameter. Grosch's Law predicts that computing power increases as a function of cost squared, or for twice the cost you get four times as much computing power. Grosch's Law using our analysis means that:

$$Power = K^1 \, (cost)^{\left(\frac{1}{-a_1}\right)} \quad Where: \left(\frac{1}{-a_1}\right) = 2; \text{ or } -a_1 = .5$$

Our regression equations yield $-a_1 = + .404$ for commercial computation, and $-a_1 = + .322$ for scientific computation. Both of these indicate that the return to scale are greater than that predicted by Grosch's Law. (For scientific computation 1962-66: Power $= K^1 \, (cost)^{2.5}$ and for commercial computation 1962-1966: Power $= K^1 \, (Cost)^{3.1}$. These returns to scale are also greater than those found during the period 1950-1962.[5]

Fig. 3. Average Yearly Shift of the Technology Curves (Power (P) Improvement for Constant Cost (C)).



conclusion

In conclusion, we find that the tremendous rate of improvement in computing power for fixed cost that we observed between 1950 and 1962 has continued and possibly slightly accelerated from 1963 through 1966 with the introduction of the third generation computers. We also find that the economies of scale predicted by Grosch's Law is supported and that today there appear to be even greater economies of scale, with larger machines providing equivalent computation at much less cost. ■

[5] For the 1950-62 period the results were that $-a_1 = +.519$ for scientific computation, and $-a_1 = +.459$ for commercial computation.