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COST OF ADDRESSING TARGETS OF UNEQUAL VALUE

Gregory H. Canavan

First strike costs are generalized to include higher value targets. As the number of weapons decreases, second strikes shift to high value targets. An increased preference for damaging high value targets or a decreased preference for preventing damage to one's own decrease first strike costs and stability. Defenses reduce second strikes, first strike costs, and the number of weapons delivered on the first striker's high value targets.

Introduction. The formalism for evaluating first strike costs and incentives for military targeting generalize to include higher value targets. That introduces two new allocations to the usual allocation between missiles and military targets, but they can be performed analytically. As the number of weapons on each side decreases, the optimal fraction of second strike weapons allocated to military values falls. The shift to high value targets is more pronounced below about 1,000 weapons for nominal parameters. Below 500 weapons the first striker's cost of action drops below its cost of inaction. A strike would induce a second strike of about 250 weapons on high value targets. An increase in the first striker's preference for damage to the other's high value targets increases or a decrease in its preference for preventing damage to its own high value targets decreases first strike costs and stability margins.

Including defenses complicates allocations slightly. The main effect is increased attrition of second strikes, particularly at larger defenses, which makes it possible to significantly reduce damage to high value targets. At 1,000 weapons, by 300 to 400 interceptors the first striker's costs are reduced to 30% below that of inaction and the number of weapons delivered on the first striker's high value targets is reduced to about 100.

Exchanges are modeled and optimized with generalizations of previous work.[1] Side U has M vulnerable missiles with m warheads each and N survivable missiles with n warheads for a total of $W = mM + nN$ warheads. Side P, whose forces and costs are denoted by primes, has M' vulnerable missiles with m' warheads each and N' survivable missiles with n' warheads for a total of $W' = m'M' + n'N'$ warheads. If U strikes first, it delivers a fraction f of its W weapons on P's vulnerable missiles and the remaining 1 – f in a first strike on value targets of magnitude

$$F = (1 - f)W. \tag{1}$$

The counter force strike of an average of $r = fW/M'$ warheads on each vulnerable missile, which gives them a survival probability Q' determined by the weapons' kill probability is $p = 1 - q$. If $[r]$ is the integer part of r, a fraction $r - [r]$ of the missiles are struck by $[r] + 1$ weapons and a fraction $[r] + 1 - r$ are struck by $[r]$, whereby

$$Q' = (r - [r])q^{([r]+1)} + ([r] + 1 - r)q^{[r]} = (1 - p(r - [r]))\, q^{[r]}, \tag{2}$$

Prime's launched second strike is

$$S' = Q'm'M' + n'N', \tag{3}$$

which is delivered on value, as residual weapons are taken to have no value. Unprime's second strike and primes first strike are obtained by conjugating (interchanging primed and unprimed terms) in Eqns. (1) to (3).

Costs. First and second strikes are converted into costs through exponential approximations to the value of the targets destroyed. It is assumed that U has $1/k$ and P has $1/k'$ military value target and that U has $1/v$ and P has $1/v'$ higher value targets. U divides its first strike between P's military and higher value targets, allocating a fraction h to the former and $1- h$ to the latter, which produces first strike costs of

$$C_{1mo} = Le^{-k'hF}, \tag{4}$$

$$C_{1vo} = Ve^{-v'(1-h)F}, \tag{5}$$

where C_{1mo} is the cost to U of its incomplete damage to P's military value and C_{1vo} is the cost to U of its incomplete damage to P's higher value targets. L is U's preference for attacking P's military targets relative to preventing damage to its own. Thus, V/L indicates U's preference for attacking P's higher value targets relative to that for attacking military targets.

P also divides its second strike between U's military and higher value targets, allocating a fraction g to the former and $1- g$ to the latter, which produces costs to first striker U of

$$C_{1ms} = 1 - e^{-kg'S'}, \tag{6}$$

$$C_{1vs} = K(1 - e^{-v(1-g')S'}), \tag{7}$$

where C_{1ms} is the cost to U of P's damage to U's military targets and C_{1vs} is the cost of P's damage to U's higher value targets. K is the priority U assigns to damage on its higher value targets relative to that given to damage on its military targets. U's cost for striking first is

$$\begin{aligned} C_1 &= C_{1m} + C_{1v} = C_{1ms} + C_{1mo} + C_{1vs} + C_{1vo} \\ &= (1 - e^{-kg'S'}) + Le^{-k'hF} \\ &\quad + K(1 - e^{-v(1-g')S'}) + Ve^{-v'(1-h)F}, \end{aligned} \tag{8}$$

The first two terms are the cost of damage to U and incomplete damage to P's military targets, which are included in previous analyses. The last two are the corresponding costs of damage to U and incomplete damage to P's higher value targets, which are new. Thus, for K and V small, the analysis reproduces previous results, while for K and V large it should migrate to a stability analysis based on high value rather than military targets. From the form of the damage functions implicit in Eq. (8) it follows that for K and V > 1 and v' < k', U sees an incentive to preferentially strike high value targets.

Allocations. U chooses f and h to minimize C_1. When higher value targets are included, P can also choose g to maximize C_1. Thus, there are two optimizations. U attempts to minimize C_1 through appropriate choice of f and h, while for every choice, P chooses g to maximize U's C_1. It is useful to treat this joint optimization in two steps. In the first, g is varied exogenously, optimizing f and h for each value of g. In the second, all three are optimized for each value of force levels.

Equal forces and target structures. Assume unprime and prime have 1/k = 1/k' = 1,000 military, 1/v = 1/v' = 100 high value targets, M = N = 500 missiles, and m = n = 2 warheads per missiles and parameters L = 0.5 and K = V = 1, i.e., a modest preference for high value targets and roughly equal preferences for striking and protecting high value targets. For those parameters, h ≈ 0.7 for all values of g, while U's allocation to missiles f increases roughly linearly to 0.4 as g increases from 0 to 1.

Figure 1 shows how the various components of cost vary with g. C_{1ms} increases with g from about 0.2 to 0.6 with diminishing returns; C_{1mo} increases slightly with g to 0.2; the overall C_{1m} increases with C_{1ms} to about 0.8. Conversely, C_{1vs} is roughly constant at small g, but falls at large g, and C_{1vo} is small throughout, so C_{1v} falls with C_{1vs} at larger g. The total C_1 increases with C_{1ms} at small g and falls with C_{1vs} at large g, so it. has a maximum of ≈ 1.7 at g ≈ 0.7, which is value of g that P would choose to maximize U's cost of striking first. Note that this maximum value of 1.7 is larger than L + V = 0.5 + 1 = 1.5, which is U's cost of inaction.

Although inappropriate, a choice of g < 0.35 by P, i.e., a second strike primarily on high value targets, would produce a U cost of first strike less than that of inaction, i.e, it would produce an incentive to strike. A strike totally on military targets, g = 1, would produce a first strike cost about equal to the cost of inaction. Thus, the proper admixture of higher value targets can stabilize configurations that would be unstable if targeting was confined to military targets.

Figure 2 shows the impact of reduced forces M = N = 250 with m = n = 2. The cost of damage to military targets again increases with g, but the reduction in forces causes C_{1v} to drop more rapidly, which shifts the optimum value of g to 0.5 and reduces the maximum in C_1 to about 1.6. As the number of missiles falls, the optimum continues to shift to smaller g. Reducing force levels at constant cost parameters shifts targeting from military to high value targets.

Optimum allocations. Since the total first and second strikes are determined by the allocation f, the secondary allocations g and h can be determined by differentiating the costs of Eq. (8) with respect to them. The partial derivative of C_1 with respect to g' determines the optimal allocation

$$g' = (v + (1/S')\ln(k/Kv)) / (k + v), \tag{9}$$

and that with respect to h determines

$$h = (v' + (1/F)\ln(Lk'/Vv')) / (k' + v'), \tag{10}$$

which are shown in Fig. 3 as functions of total force level W as the number of doublet U and P vulnerable and survivable missiles are reduced equally. U's allocation to missiles, f, is roughly constant at 0.25. U's allocation of its first strike to military targets, h, and P's restrike on military targets, g, fall from about 0.75 at W = 2,000 to 0.55 at 500, after which they fall rapidly to zero by 300. Thus, below about 1,000 weapons, second strikes shift rapidly to high value targets.

Figure 4 shows the total number of weapons allocated to high value targets in first and second strikes as functions of the total number of weapons available. At 2,000 weapons they are about 400 and 300 weapons, or about 20 and 15% of the total, respectively. By W = 500 they are 300 and 225, reflecting the shift to high value shown in Fig. 3. For smaller values they fall rapidly, but constitute most of the remaining weapons.

Figure 5 shows the resulting costs. The cost for damage to value changes little, but the cost for damage to military targets falls from about 0.75 to 0.5, so the total cost falls below the cost of inaction by about 600 weapons even when they are targeted optimally between military and high value targets. Figure 6 provides more detail on the variation of component costs. C_{1m} only falls about 30%, but its components vary more: C_{1ms} falls 100%; C_{1mo} increases a like amount. Similarly, C_{1vs} and C_{1vo} vary about 50%, but C_{1v} varies little. Modest changes in aggregate costs are the result of larger changes in components—particularly at small forces.

Sensitivity to cost parameters. Sensitivity to L is understood from preveious analyses of purely military target structures. Sensitivity to V, which reflects U's preference for damage to

P's high value targets is straightforward. The calculations are done for the small force W = 400, because Eq. (10) indicates that for large forces, h ~ v' / (k' + v') = 1/k' / (1/k' + 1/v'), i.e., that U targets military targets in proportion to their fraction of the total. For small forces, the allocation is more complex. There,as V increases, h falls from unity at V = 0 to 0 at V ≈ 1. Figure 7 shows that has little impact on military or high value target costs for V < 1. However, C_1 increases with V for any first strike and allocations, so the cost of inaction L + V increases linearly with V, crossing C_1 at V ≈ 1. Thus, small V, i.e, little preference for damage to the other's high value targets, leads to inaction, while large V, i.e, preference for damaging high value targets, could lead to strikes.

Figure 8 shows the strike allocations as functions of K, which is U's preference for avoiding damage to it own high value targets. The allocation to missiles is again about 0.25, increasing slightly for very small or large K, which produces corresponding increases in the weapons per missile r and decreases in their survival probability Q' there. h is about 0.55, falling slightly at extreme K. g falls from about 0.8 to 0.4 as K increases from 0.25 to 2.3.

Figure 9 shows the variation of component costs caused by these variations in allocations. Costs due to military targets fall slightly at small K. Costs for high value targets increase roughly in proportion to K--largely due to the cost of damage to U's value, which is proportional to K. Since K does not enter the cost of inaction, it remains fixed at L + V = 1.5. Thus, small K make the cost of action smaller than that of inaction, and large K make it larger. Said another way, a low concern for one's own high value targets reduces stability margin, and a large concern increases it.

Defenses primarily reduce second strikes in this analysis. Adding a term –I, where I is the number of U interceptors, does not change the optimal value of h. It changes the denominator of the first term in Eq. (9) to S' – I, which decreases g'. It also changes the second strike in the iterative solution for the allocation f. Figure 10 shows the allocations as functions of I. f increases from 0.25 to 0.5 at I = 350, where it becomes efficient to increase the weapons on each vulnerable missile M from r = 1 to 2, which decreases Q' from 0.2 to 0.04. That decreases h discontinuously; g falls throughout for the reason discussed above.

Figure 11 shows the resulting costs. The cost to U for military targets falls to I = 300; the cost for high value targets falls for larger I. The total cost decreases throughout, falling below the cost of inaction at about I = 100. Figure 12 shows the weapons delivered on high value targets in

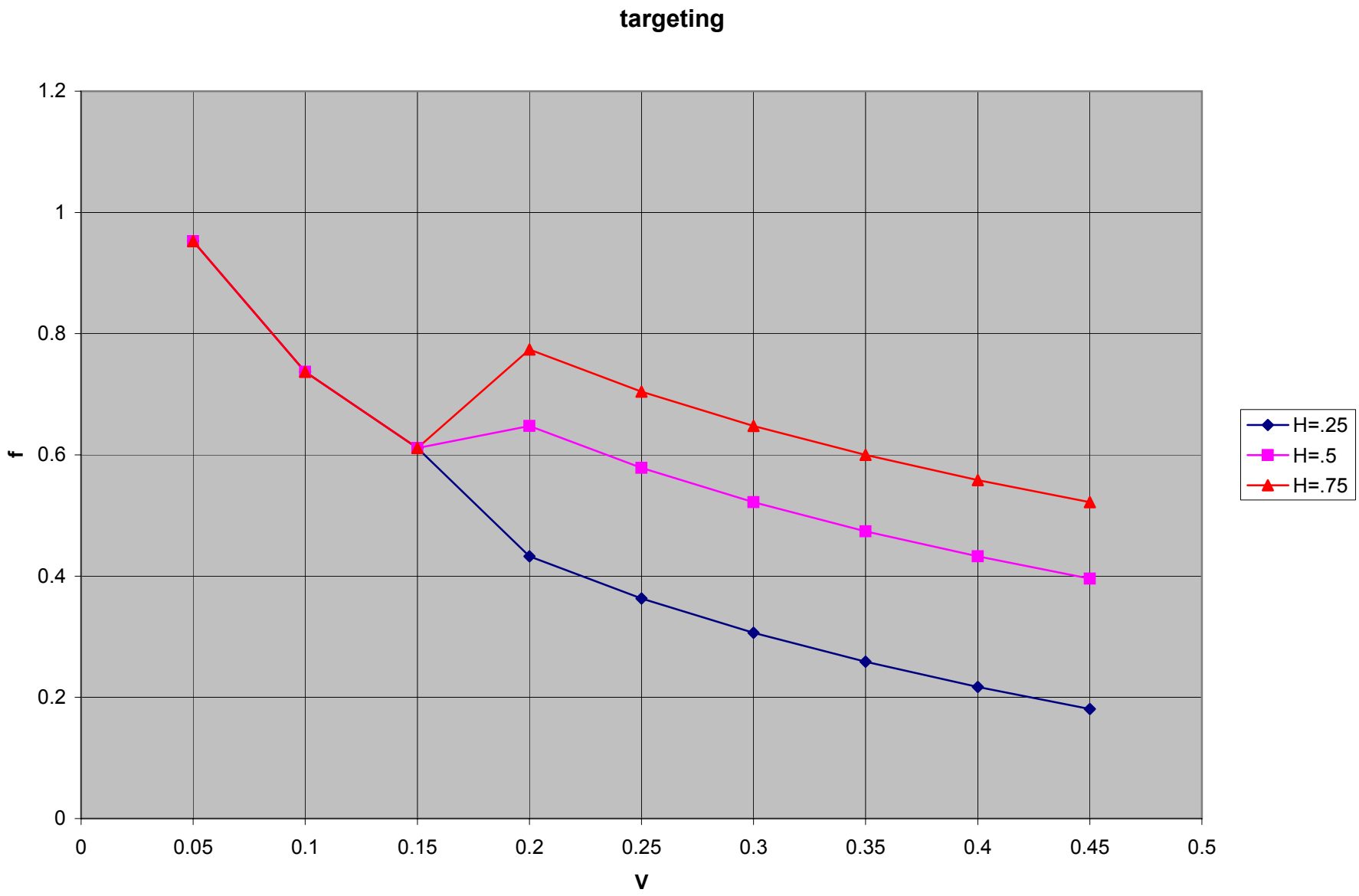
first and second strikes. At small I, the top curve is the first strike, F; the second is the second strike, S; the third is the weapons on P's value in U's first strike; and the fourth is P's weapons on U's high value targets in its second strike. F is about 750 until it becomes effective to shift additional weapons to missiles at I = 350. The second strike S falls throughout with survivability and interceptor losses. U's first strike on high value remains relatively constant at 330 to 310 weapons. P's strike on value remains roughly constant to I = 350, where it falls more sharply due to reduced prelaunch survivability under increased weapons per missile. Of these trends, perhaps the most useful is U's incentive to do additional damage limiting with its defenses, which can significantly reduce the damage to its high value targets.

Summary and conclusions. The formalism developed for addressing first strike costs and incentives used for the analysis of military targeting generalizes in a natural and efficient way to include higher value targets. This introduces two new allocations in addition to the allocation between missiles and military targets discussed in earlier analyses. They are the allocation of the first strike between military and high value targets and the allocation of the second strike between the first striker's military and high value targets. The new allocations can be performed analytically, given the iterative solution of the allocation of the first strike between missiles and value. As the number of weapons on each side decreases, the optimal fraction of second strike weapons allocated to military values falls. This implies a shift of targeting towards high value targests that becomes sharper below about 1,000 weapons for nominal conditions. Below 500 weapons the first striker's cost of action drops below its cost of inaction. A strike there would induce a second strike of about 250 weapons on high value targets. As the first striker's preference for damage to the other's high value targets increases, or its preference for preventing damage to its own high value targets decreases, first strike costs and stability margins are reduced.

When defenses are included, allocations are complicated slightly, but the main effect is the increased attrition and of second strikes, particularly at larger defenses. That makes it possible to significantly reducing damage to high value targets. At a level of 1,000 weapons, the first striker's costs are strongly reduced by > 300 interceptors. By 400 interceptors the first striker's cost is reduced to 30% below that of inaction and the number of weapons delivered on the first striker's high value targets is reduced to about 100. To fully evaluate the impact of these results on stability it is necessary to examine the other sides' first strike costs as well.

References

[1] G. Canavan, "Decision Analysis of Bi- and Tri-Lateral Engagements," Roundtable on Stability, US State Department, IDA, November 2000; Los Alamos National Laboratory Report LA-UR-00-5737, November 2000.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0.8
0.6
0.4
0.2
0
f
0
0.05
0.1
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0.3
0.35
0.4
0.45
0.5
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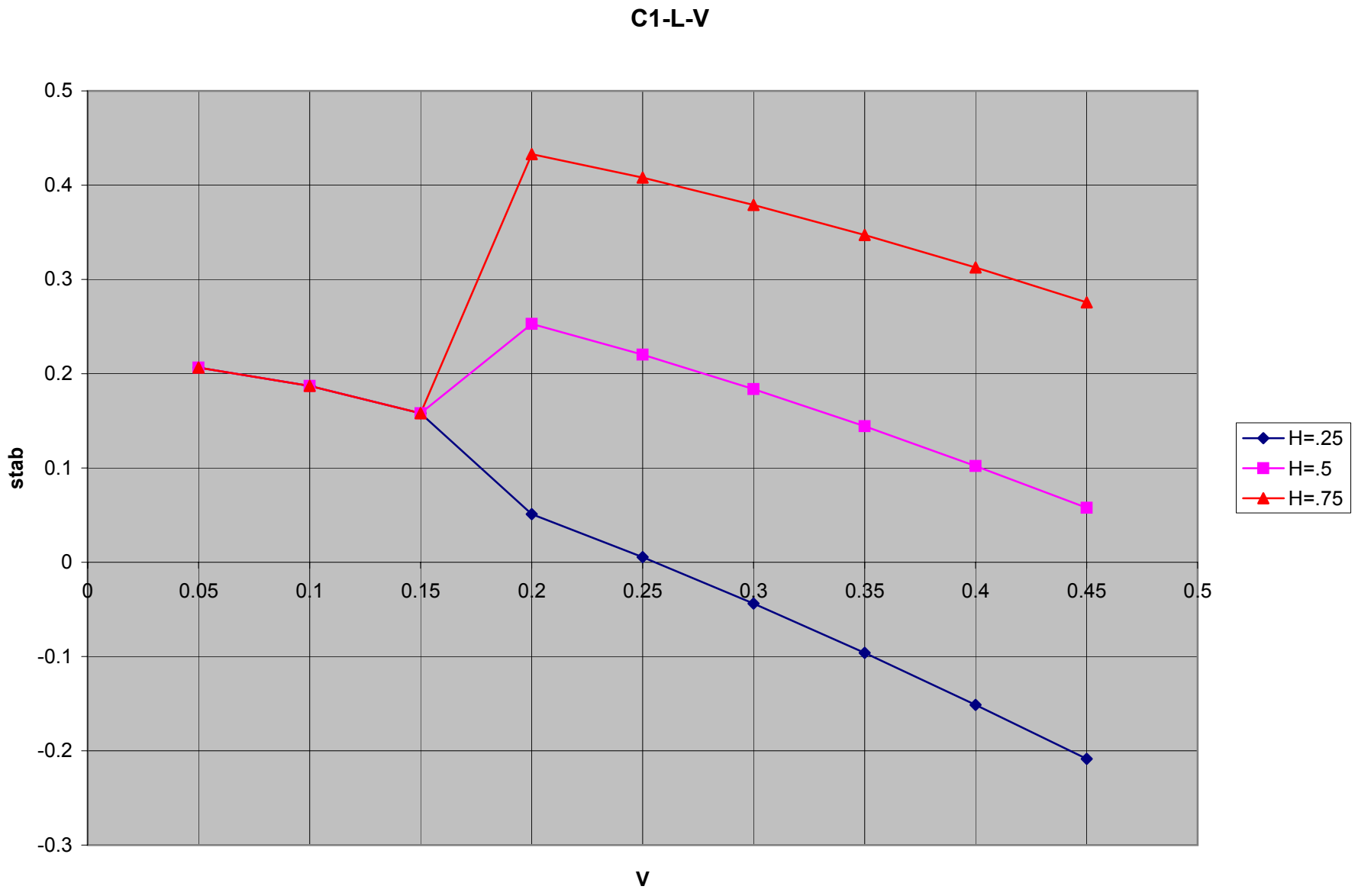
H=.5
H=.75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-0.3
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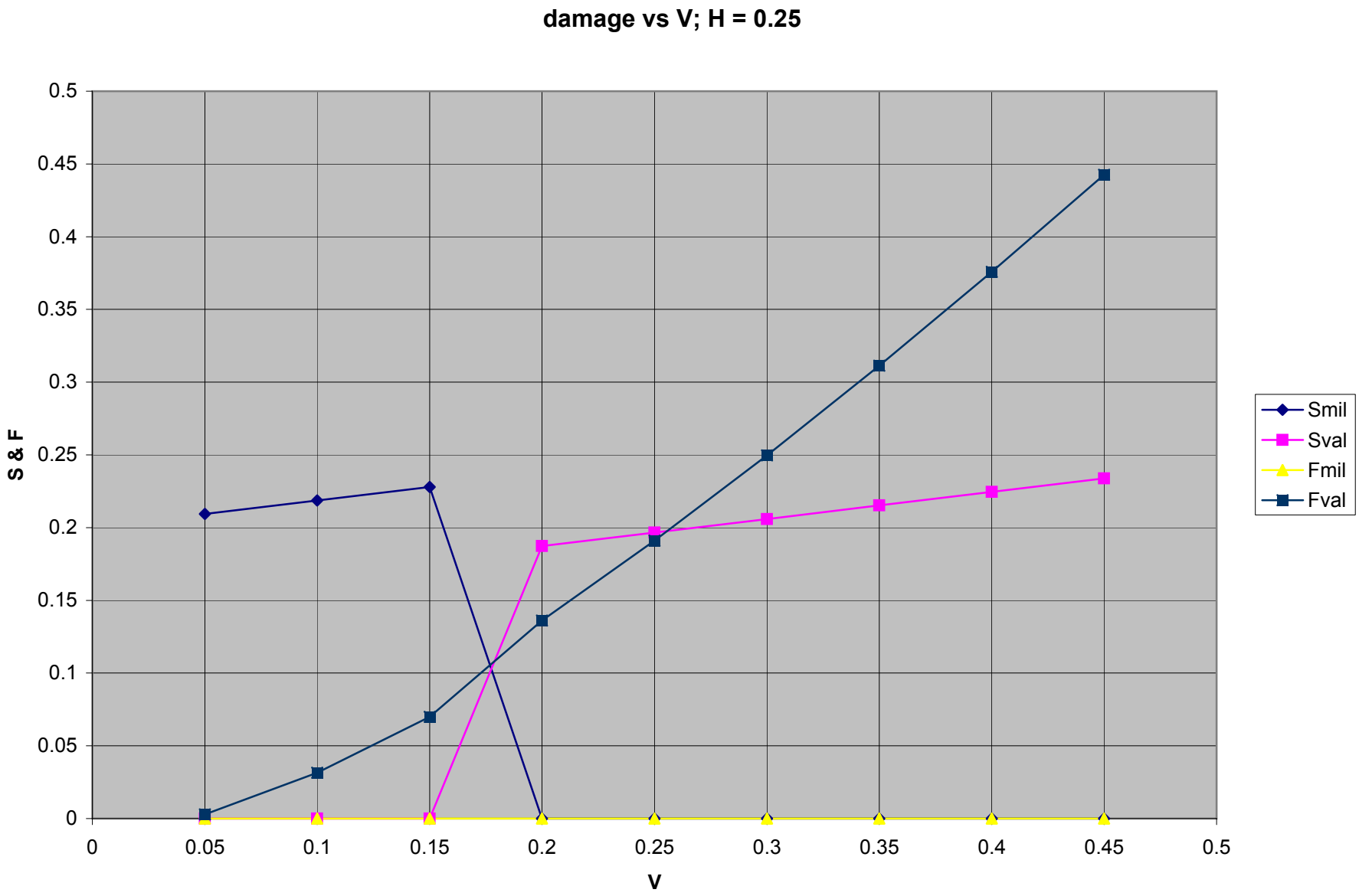
H=.75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S & F
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0.45
0.5
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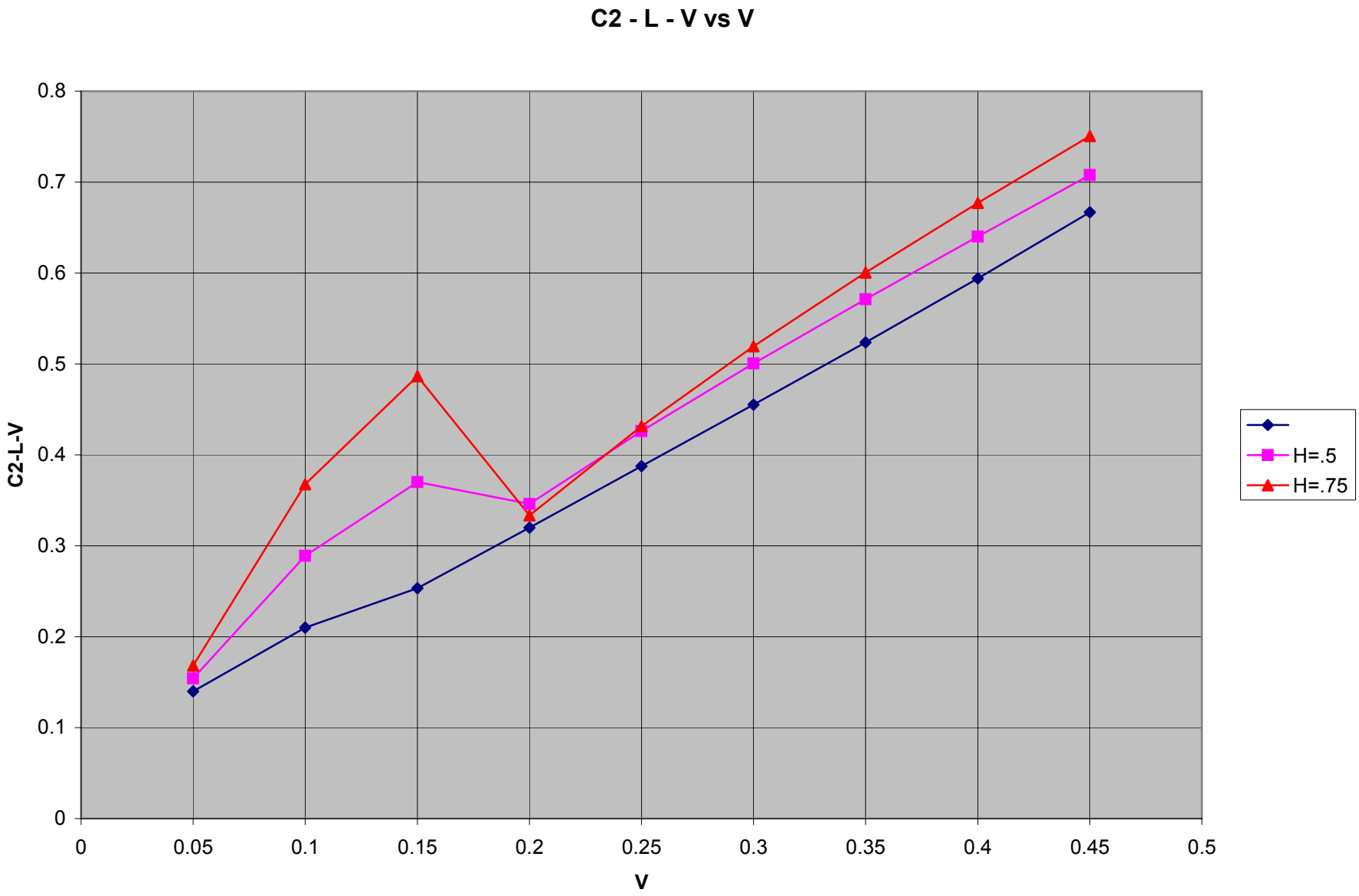
Sval
Fmil
Fval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C2-L-V
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0.2
0.3
0.4
0.5
0.6
0.7
0.8
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5
H=.5
H=.75

v	L	k	v-Lk	h	V	Hterm	H	Lk-Vv	g	Gterm	p	q	lnq	m	M/W	H=.25	H=.5	H=.75	Q	M	nN	S	F	H=.25	H=.5	H=.75	G2	H2		H=.5	H=.75	Smil	Sval	Fmil	Fval
0.003	0.6	0.001	0.002	0	0.05	2E-04	0.25	5E-04	1	0.001	0.8	0	-2	2	0.5	0.95	1	0.95	0	100	200	209	19	0.21	0.206	0.21	8E-04	6E-04	0.14	0.15	0.17	0.21	0	0	0
0.003	0.6	0.001	0.002	0	0.1	3E-04	0.25	3E-04	1	0.001	0.8	0	-2	2	0.5	0.74	0.7	0.74	0.1	100	200	219	105	0.19	0.187	0.19	8E-04	6E-04	0.21	0.29	0.37	0.22	0	0	0.03
0.003	0.6	0.001	0.002	0	0.15	5E-04	0.25	2E-04	1	0.001	0.8	0	-2	2	0.5	0.61	0.6	0.61	0.1	100	200	228	155	0.16	0.158	0.16	8E-04	6E-04	0.25	0.37	0.49	0.23	0	0	0.07
0.003	0.6	0.001	0.002	0	0.2	6E-04	0.25	0	0	8E-04	0.8	0	-2	2	0.5	0.43	0.6	0.77	0.2	100	200	250	227	0.05	0.253	0.43	8E-04	6E-04	0.32	0.35	0.33	0	0.19	0	0.14
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0.003	0.6	0.001	0.002	0	0.35	0.001	0.25	-5E-04	0	8E-04	0.8	0	-2	2	0.5	0.26	0.5	0.6	0.4	100	200	287	297	-0.1	0.144	0.35	8E-04	0.001	0.52	0.57	0.6	0	0.22	0	0.31
0.003	0.6	0.001	0.002	0	0.4	0.001	0.25	-6E-04	0	8E-04	0.8	0	-2	2	0.5	0.22	0.4	0.56	0.5	100	200	299	313	-0.15	0.102	0.31	8E-04	0.001	0.59	0.64	0.68	0	0.22	0	0.38
0.003	0.6	0.001	0.002	0	0.45	0.001	0.25	-8E-04	0	8E-04	0.8	0	-2	2	0.5	0.18	0.4	0.52	0.6	100	200	312	328	-0.21	0.058	0.28	8E-04	0.001	0.67	0.71	0.75	0	0.23	0	0.44

v	L	k	v-Lk	h	Voth	Hterm	Hself	Lk-Vv	g	Gterm	p	q	lnq	m	M/W	f	Q	M	nN	S	F	C1-L-V	G2	H2	C2-L-V
0.003	0.6	0.001	0.002	0	0.05	2E-04	0.5	5E-04	1	0.001	0.8	0	-2	2	0.5	0.95	0	100	200	209	19	0.21	0.002	6E-04	0.15
0.003	0.6	0.001	0.002	0	0.1	3E-04	0.5	3E-04	1	0.001	0.8	0	-2	2	0.5	0.74	0.1	100	200	219	105	0.19	0.002	6E-04	0.29
0.003	0.6	0.001	0.002	0	0.15	5E-04	0.5	2E-04	1	0.001	0.8	0	-2	2	0.5	0.61	0.1	100	200	228	155	0.16	0.002	6E-04	0.37
0.003	0.6	0.001	0.002	0	0.2	6E-04	0.5	0	0	0.002	0.8	0	-2	2	0.5	0.65	0.1	100	200	225	141	0.25	0.002	6E-04	0.35
0.003	0.6	0.001	0.002	0	0.25	8E-04	0.5	-2E-04	0	0.002	0.8	0	-2	2	0.5	0.58	0.2	100	200	231	169	0.22	0.002	8E-04	0.43
0.003	0.6	0.001	0.002	0	0.3	9E-04	0.5	-3E-04	0	0.002	0.8	0	-2	2	0.5	0.52	0.2	100	200	237	191	0.18	0.002	9E-04	0.5
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0.003	0.6	0.001	0.002	0	0.45	0.001	0.5	-8E-04	0	0.002	0.8	0	-2	2	0.5	0.4	0.3	100	200	256	242	0.06	0.002	0.001	0.71

v	L	k	v-Lk	h	Voth	Hterm	Hself	Lk-Vv	g	Gterm	p	q	lnq	m	M/W	f	Q	M	nN	S	F	C1-L-V	G2	H2	C2-L-V
0.003	0.6	0.001	0.002	0	0.05	2E-04	0.75	5E-04	1	0.001	0.8	0	-2	2	0.5	0.95	0	100	200	209	19	0.21	0.002	6E-04	0.17
0.003	0.6	0.001	0.002	0	0.1	3E-04	0.75	3E-04	1	0.001	0.8	0	-2	2	0.5	0.74	0.1	100	200	219	105	0.19	0.002	6E-04	0.37
0.003	0.6	0.001	0.002	0	0.15	5E-04	0.75	2E-04	1	0.001	0.8	0	-2	2	0.5	0.61	0.1	100	200	228	155	0.16	0.002	6E-04	0.49
0.003	0.6	0.001	0.002	0	0.2	6E-04	0.75	0	0	0.002	0.8	0	-2	2	0.5	0.77	0.1	100	200	217	90	0.43	0.002	6E-04	0.33
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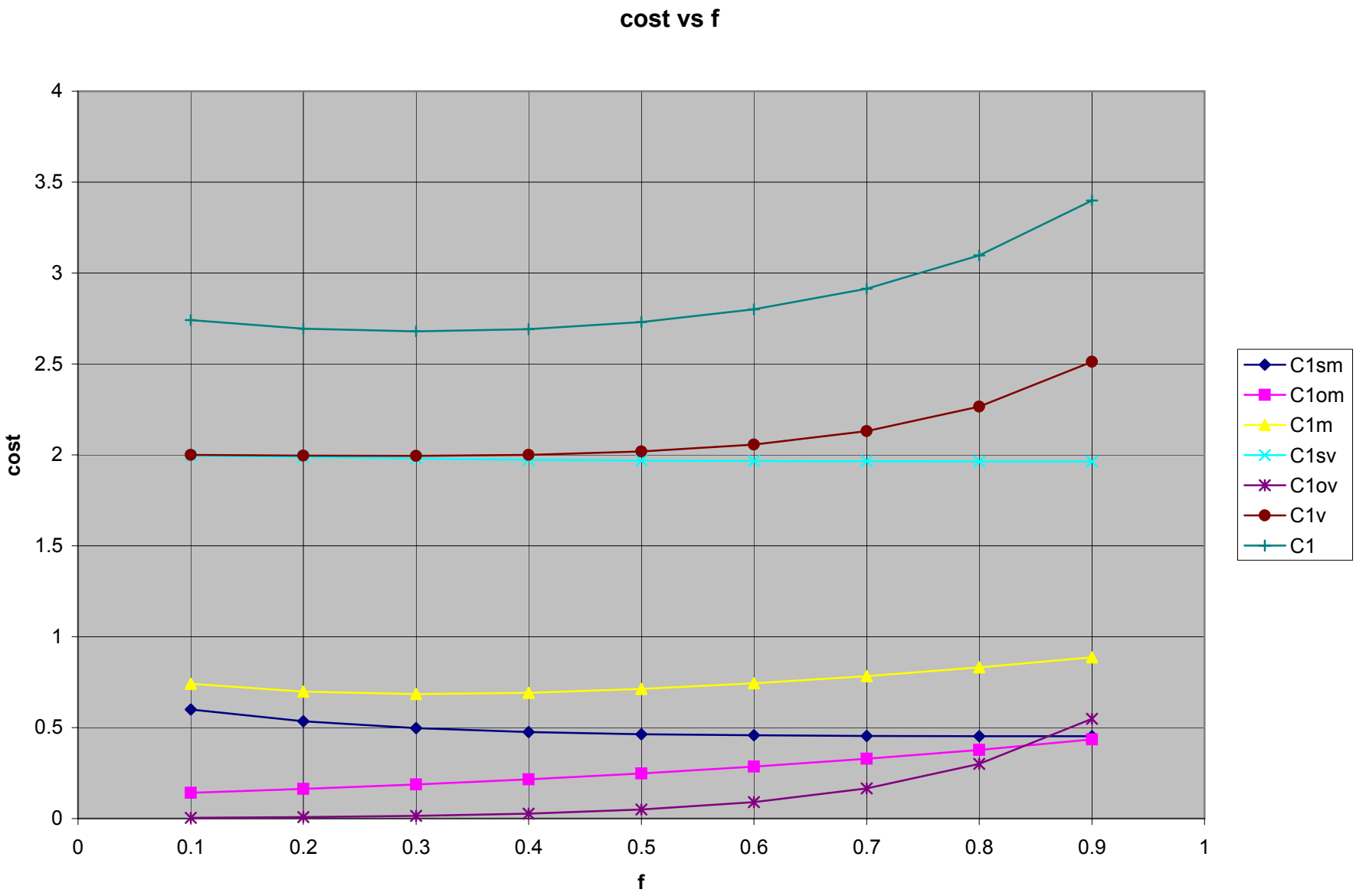
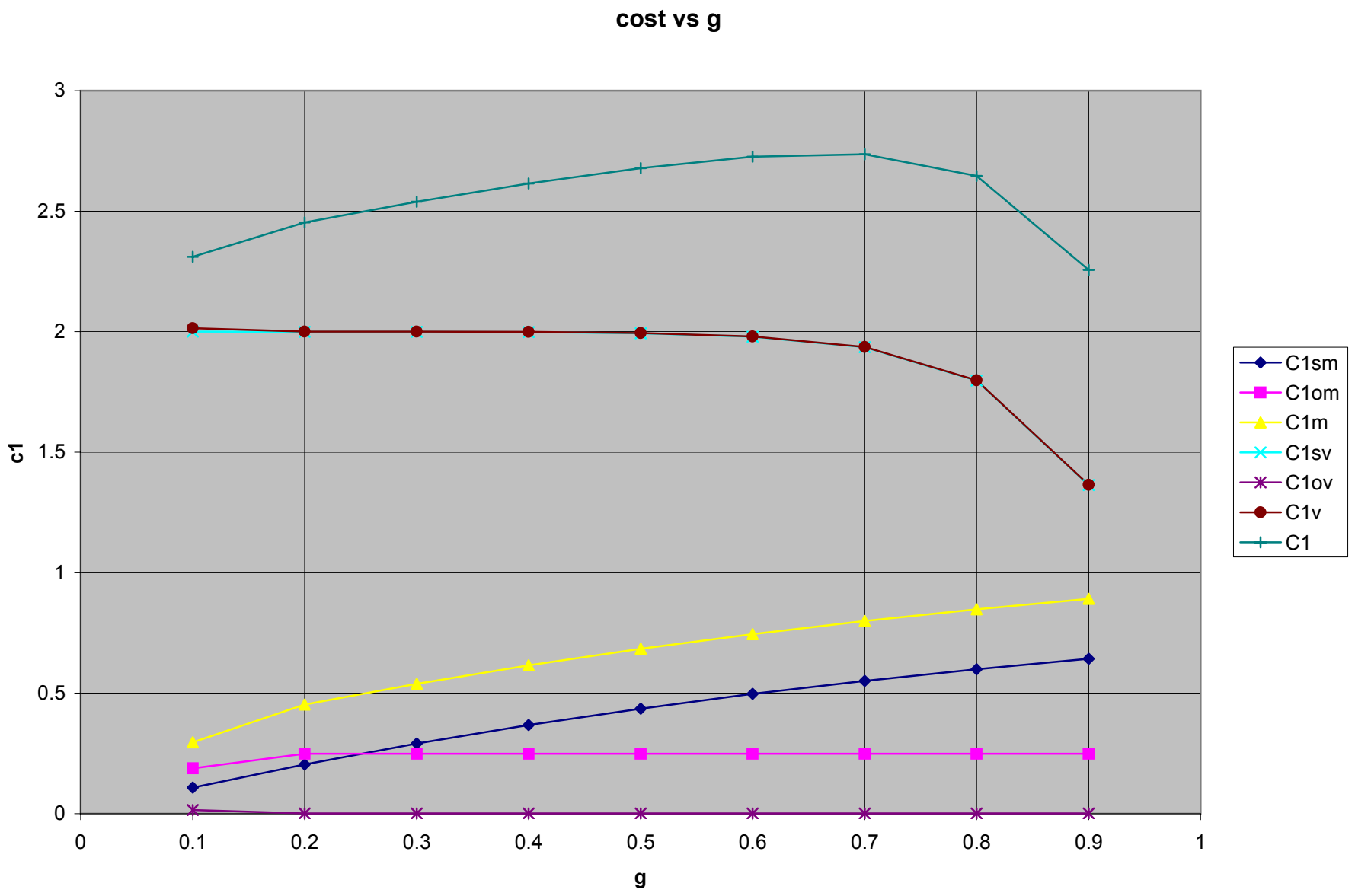
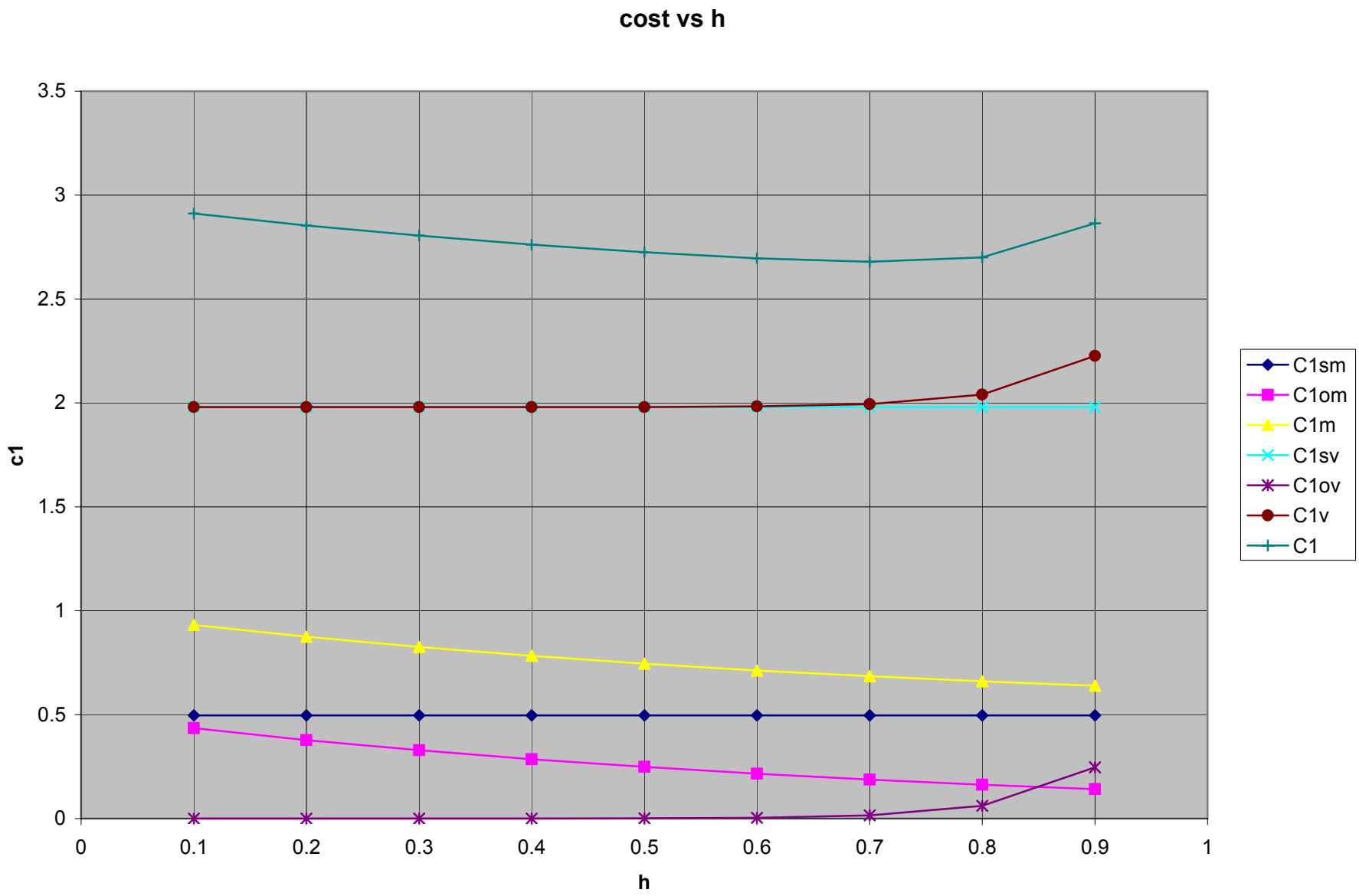
0.003	0.6	0.001	0.002	0	0.35	0.001	0.75	-5E-04	0	0.002	0.8	0	-2	2	0.5	0.6	0.1	100	200	229	160	0.35	0.002	0.001	0.6
0.003	0.6	0.001	0.002	0	0.4	0.001	0.75	-6E-04	0	0.002	0.8	0	-2	2	0.5	0.56	0.2	100	200	233	177	0.31	0.002	0.001	0.68
0.003	0.6	0.001	0.002	0	0.45	0.001	0.75	-8E-04	0	0.002	0.8	0	-2	2	0.5	0.52	0.2	100	200	237	191	0.28	0.002	0.001	0.75
																f						C1-L-V			C2-L-V


cost vs f
cost
f
0
0.5
1
1.5
2
2.5
3
3.5
4
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
C1sm
C1om
C1m
C1sv
C1ov
C1v
C1


cost vs g
c1
g
0
0.5
1
1.5
2
2.5
3
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
C1sm
C1om
C1m
C1sv
C1ov
C1v
C1


cost vs h
3.5
3
2.5
2
1.5
1
0.5
0
c1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
h
C1sm
C1om
C1m
C1sv
C1ov
C1v
C1

k	v	p	q	L	K	V	m	M	n	N	W	f	g	h	F	Q	S	C1sm	C1om	C1m	C1sv	C1o
0.001	0.01	0.8	0.2	0.5	2	1	2	500	2	500	2000	0.1	0.6	0.7	1800	0.53	1525	0.6	0.142	0.741	2	
0.001	0.01	0.8	0.2	0.5	2	1	2	500	2	500	2000	0.2	0.6	0.7	1600	0.28	1276	0.535	0.163	0.698	1.99	0.0
0.001	0.01	0.8	0.2	0.5	2	1	2	500	2	500	2000	0.3	0.6	0.7	1400	0.14	1145	0.497	0.188	0.685	1.98	0.0
0.001	0.01	0.8	0.2	0.5	2	1	2	500	2	500	2000	0.4	0.6	0.7	1200	0.08	1076	0.476	0.216	0.692	1.97	0.0
0.001	0.01	0.8	0.2	0.5	2	1	2	500	2	500	2000	0.5	0.6	0.7	1000	0.04	1040	0.464	0.248	0.712	1.97	0.0
0.001	0.01	0.8	0.2	0.5	2	1	2	500	2	500	2000	0.6	0.6	0.7	800	0.02	1021	0.458	0.286	0.744	1.97	0.0
0.001	0.01	0.8	0.2	0.5	2	1	2	500	2	500	2000	0.7	0.6	0.7	600	0.01	1011	0.455	0.329	0.783	1.96	0.1
0.001	0.01	0.8	0.2	0.5	2	1	2	500	2	500	2000	0.8	0.6	0.7	400	0.01	1006	0.453	0.378	0.831	1.96	0.
0.001	0.01	0.8	0.2	0.5	2	1	2	500	2	500	2000	0.9	0.6	0.7	200	0	1003	0.452	0.435	0.887	1.96	0.5
k	v	p	q	L	K	V	m	M	n	N	W	f	g	h	F	Q	S	C1sm	C1om	C1m	C1sv	C1o
0.001	0.01	0.8	0.2	0.5	2	1	2	500	2	500	2000	0.3	0.1	0.7	1400	0.14	1145	0.108	0.188	0.296	2	0.0
0.001	0.01	0.8	0.2	0.5	2	1	2	500	2	500	2000	0.3	0.2	0.5	1400	0.14	1145	0.205	0.248	0.453	2	
0.001	0.01	0.8	0.2	0.5	2	1	2	500	2	500	2000	0.3	0.3	0.5	1400	0.14	1145	0.291	0.248	0.539	2	
0.001	0.01	0.8	0.2	0.5	2	1	2	500	2	500	2000	0.3	0.4	0.5	1400	0.14	1145	0.367	0.248	0.616	2	
0.001	0.01	0.8	0.2	0.5	2	1	2	500	2	500	2000	0.3	0.5	0.5	1400	0.14	1145	0.436	0.248	0.684	1.99	
0.001	0.01	0.8	0.2	0.5	2	1	2	500	2	500	2000	0.3	0.6	0.5	1400	0.14	1145	0.497	0.248	0.745	1.98	
0.001	0.01	0.8	0.2	0.5	2	1	2	500	2	500	2000	0.3	0.7	0.5	1400	0.14	1145	0.551	0.248	0.8	1.94	
0.001	0.01	0.8	0.2	0.5	2	1	2	500	2	500	2000	0.3	0.8	0.5	1400	0.14	1145	0.6	0.248	0.848	1.8	
0.001	0.01	0.8	0.2	0.5	2	1	2	500	2	500	2000	0.3	0.9	0.5	1400	0.14	1145	0.643	0.248	0.891	1.36	
k	v	p	q	L	K	V	m	M	n	N	W	f	g	h	F	Q	S	C1sm	C1om	C1m	C1sv	C1o
0.001	0.01	0.8	0.2	0.5	2	1	2	500	2	500	2000	0.3	0.6	0.1	1400	0.14	1145	0.497	0.435	0.932	1.98	
0.001	0.01	0.8	0.2	0.5	2	1	2	500	2	500	2000	0.3	0.6	0.2	1400	0.14	1145	0.497	0.378	0.875	1.98	
0.001	0.01	0.8	0.2	0.5	2	1	2	500	2	500	2000	0.3	0.6	0.3	1400	0.14	1145	0.497	0.329	0.825	1.98	

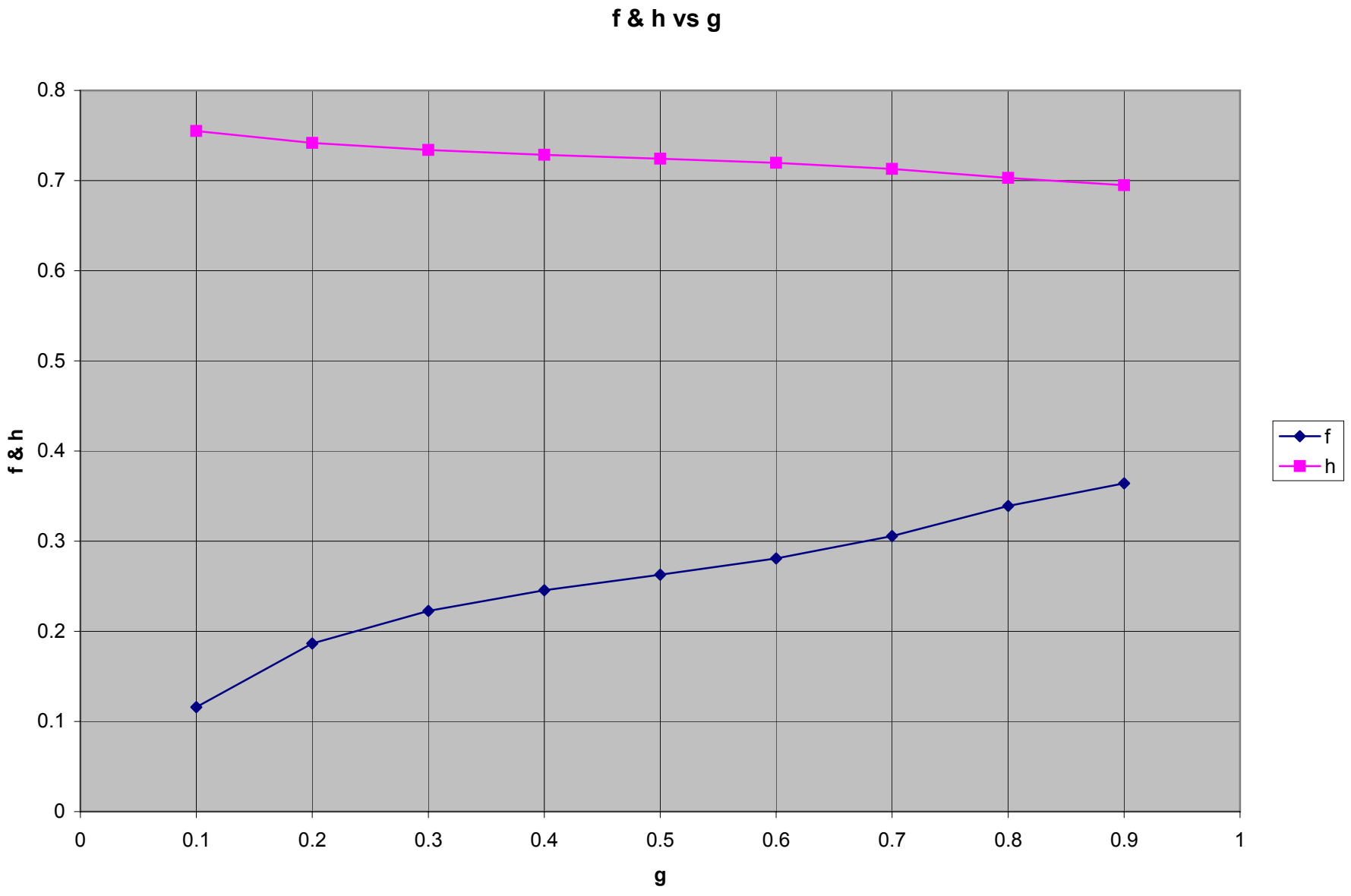
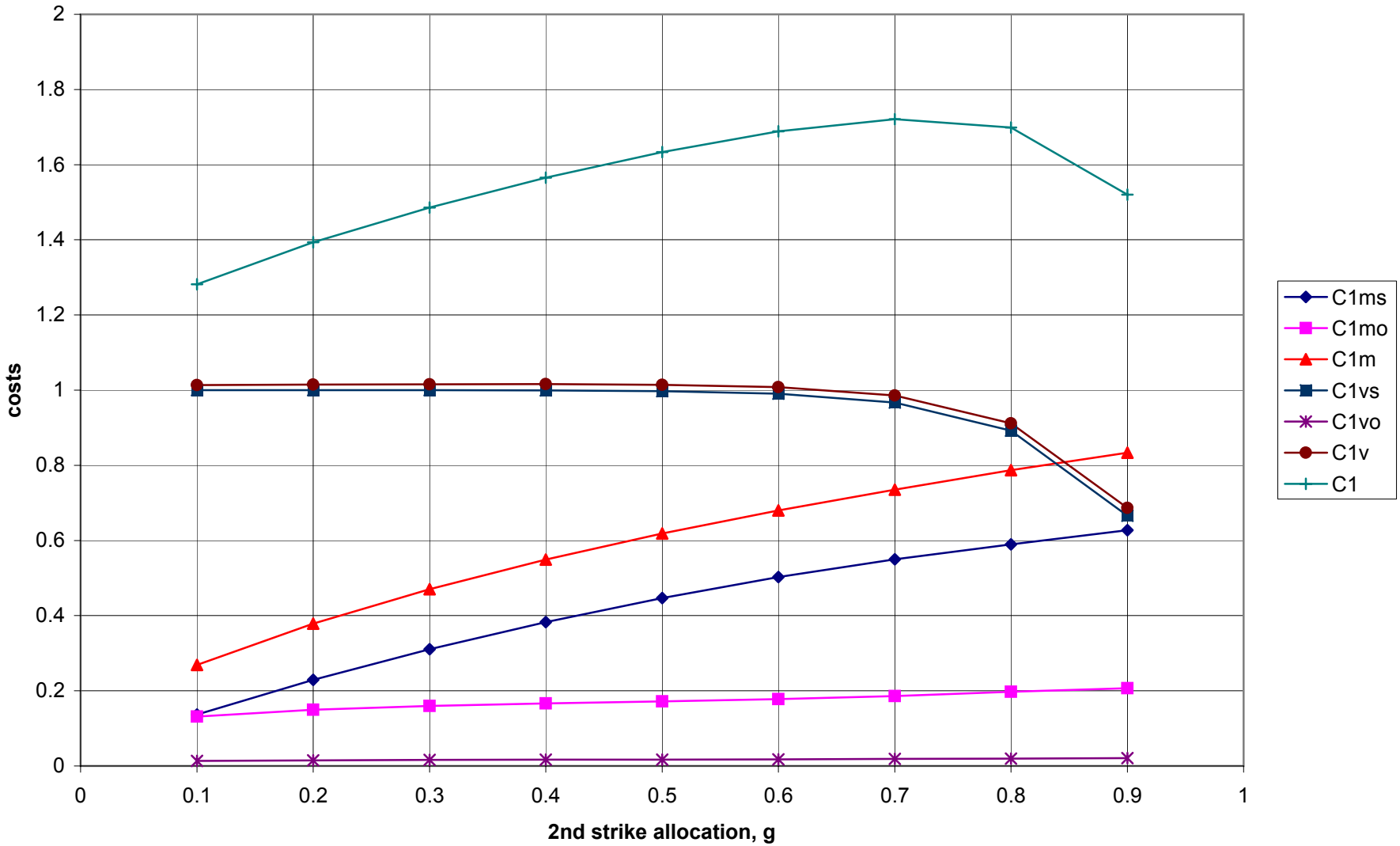
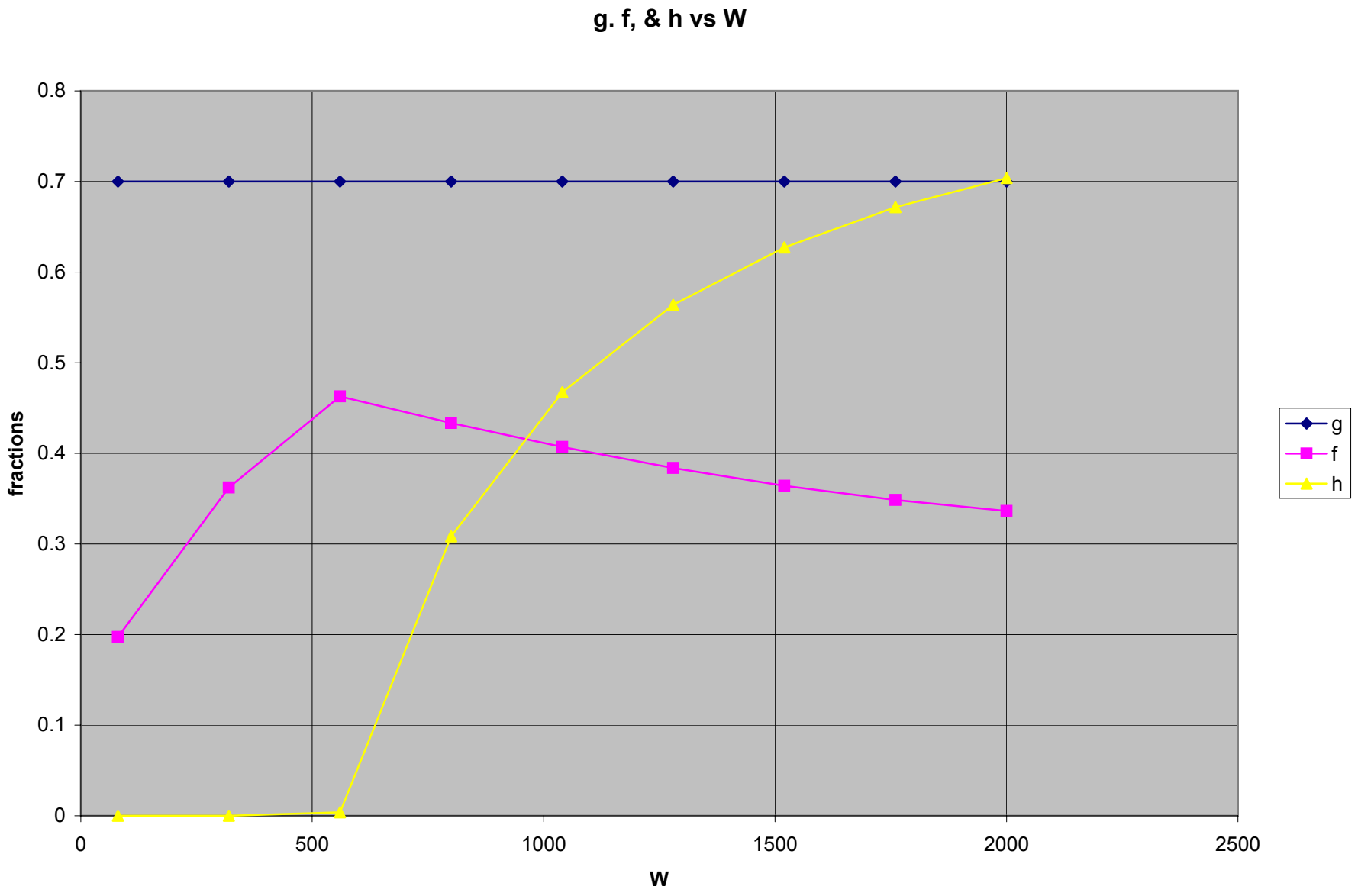
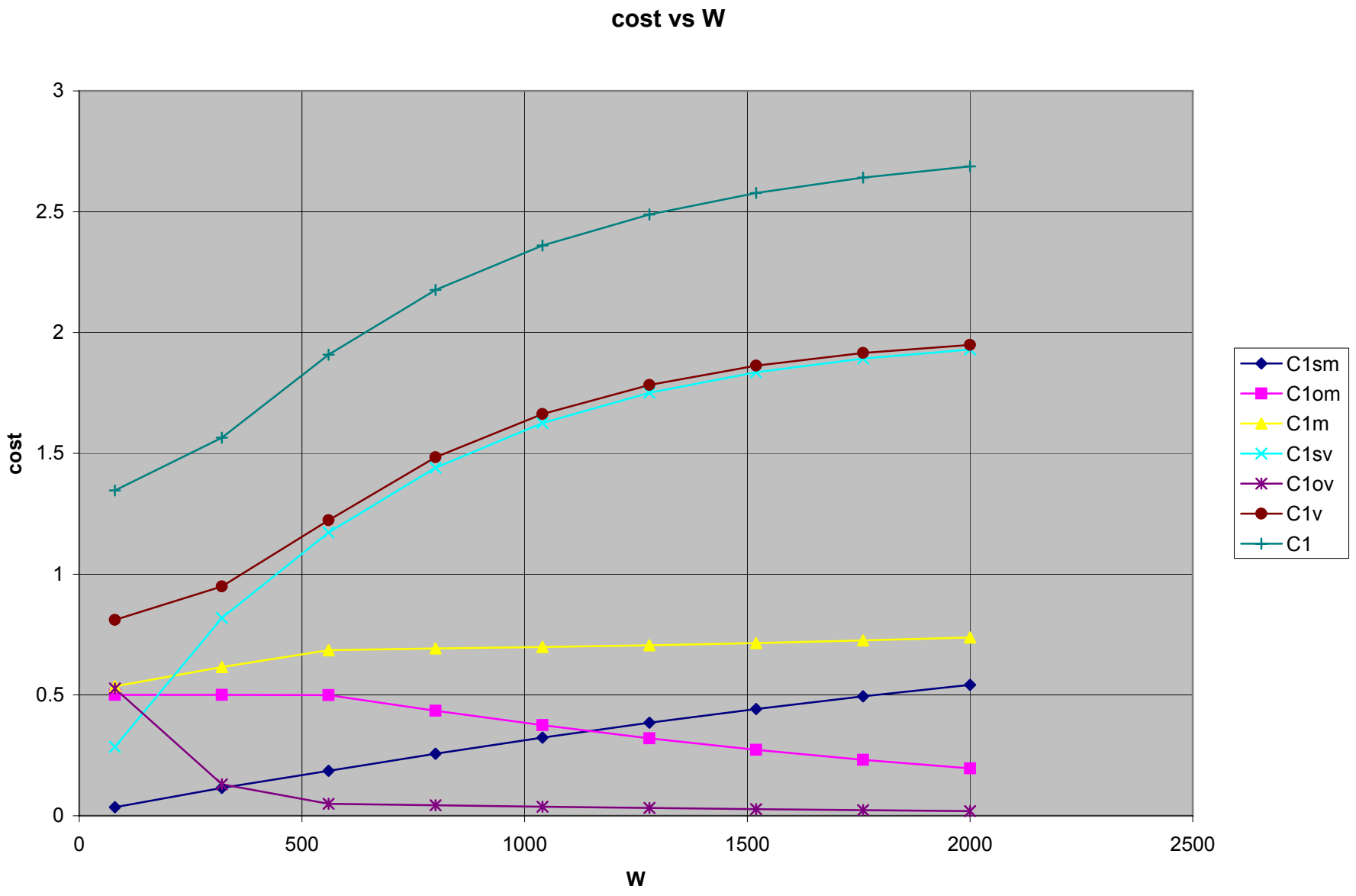

f & h vs g
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
f & h
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
g
f
h

Fig. 1. costs vs 2nd strike allocation, g

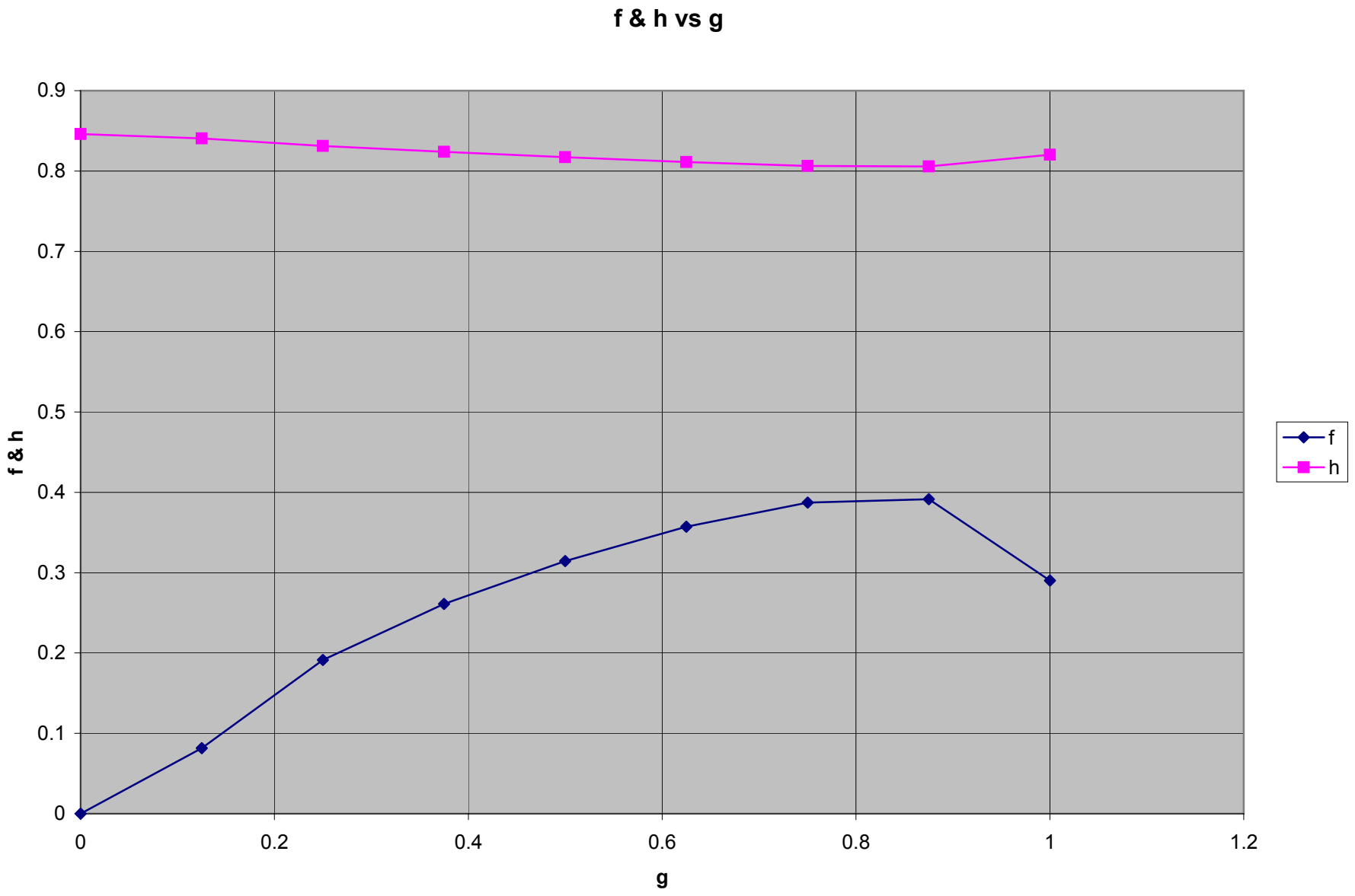


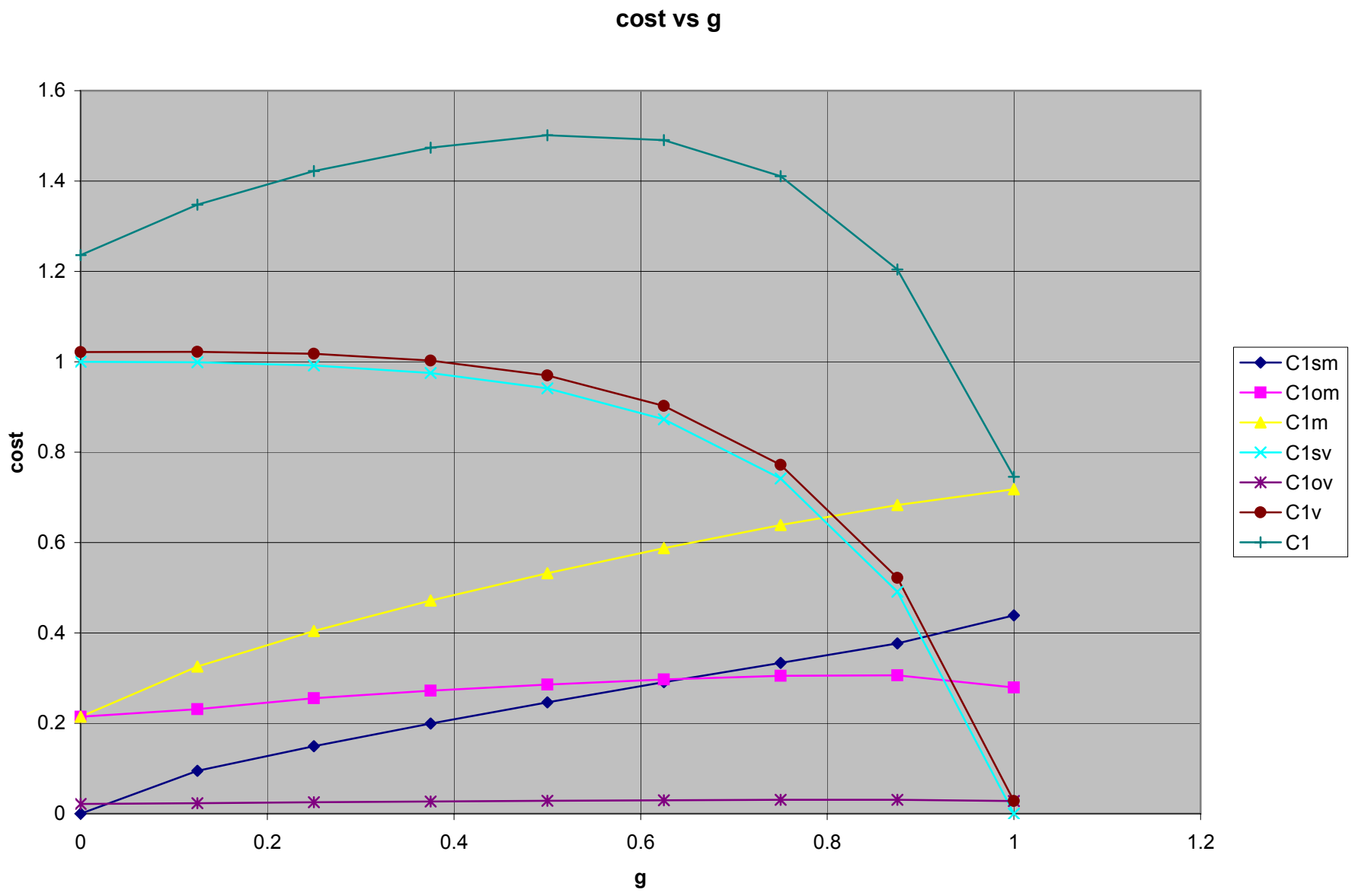
k	v	p	q	L	K	V	m	M	n	N	W	g	f	h	F	Q	S	C1ms	C1mo	C1m	C1vs	C1v
0.001	0.01	0.8	0.2	0.5	1	1	2	500	2	500	2000	0.1	0.1	0.8	1768	0.47	1474	0.137	0.132	0.269	1	0.0
0.001	0.01	0.8	0.2	0.5	1	1	2	500	2	500	2000	0.2	0.2	0.7	1627	0.3	1301	0.229	0.15	0.379	1	0.0
0.001	0.01	0.8	0.2	0.5	1	1	2	500	2	500	2000	0.3	0.2	0.7	1555	0.24	1239	0.31	0.16	0.47	1	0.0
0.001	0.01	0.8	0.2	0.5	1	1	2	500	2	500	2000	0.4	0.2	0.7	1509	0.21	1206	0.383	0.167	0.549	1	0.0

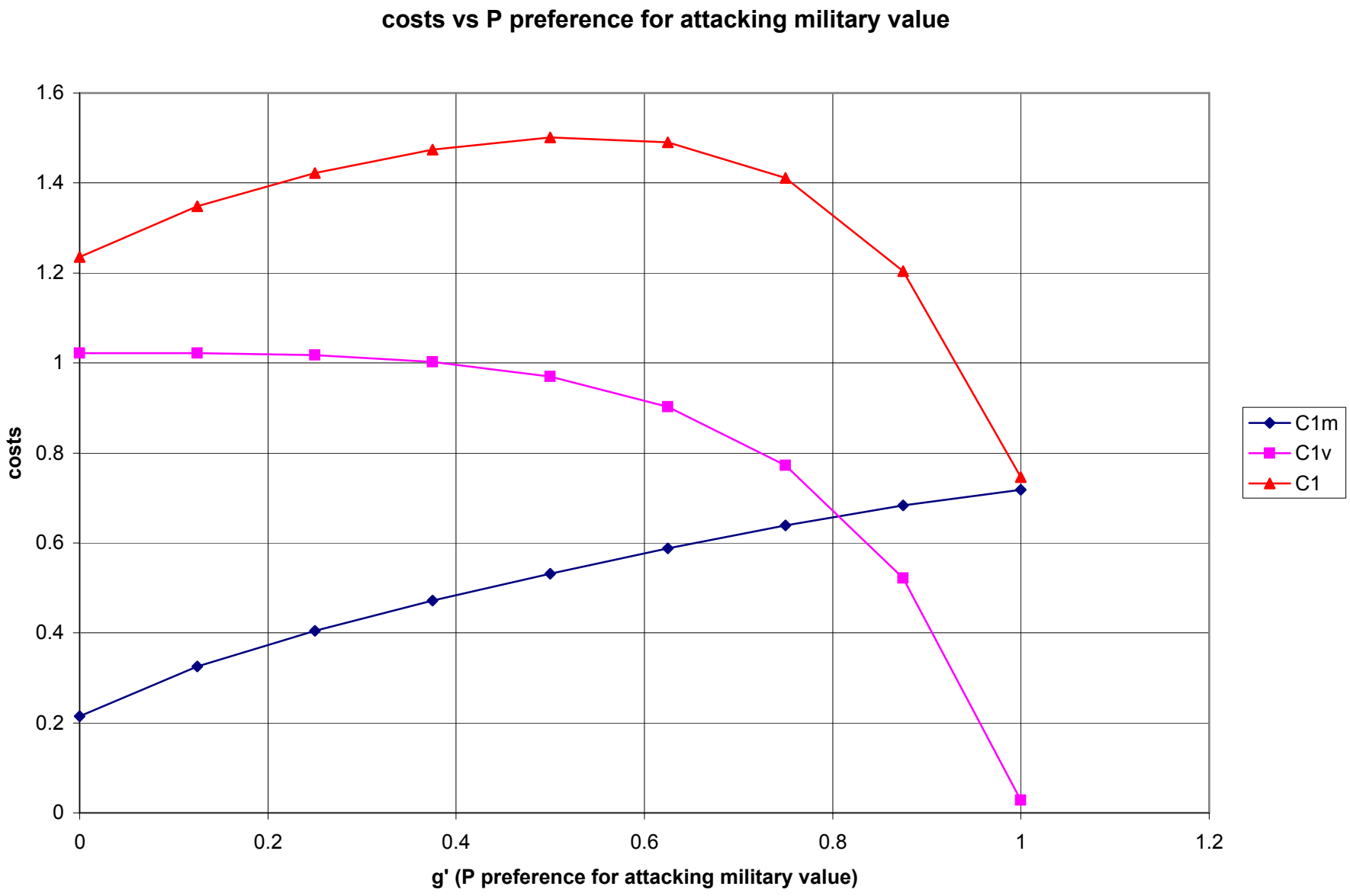

g. f, & h vs W
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
fractions
0
500
1000
1500
2000
2500
W
g
f
h


cost vs W
cost
W
0
0.5
1
1.5
2
2.5
3
0
500
1000
1500
2000
2500
C1sm
C1om
C1m
C1sv
C1ov
C1v
C1

k	v	p	q	L	K	V	m	M	n	N	W	g	f	h	F	Q	S	C1sm	C1om	C1m	C1sv	C1ov	C1
0.001	0.01	0.8	0.2	0.5	2	1	2	500	2	500	2000	0.7	0.3	0.7	1327	0.11	1115	0.542	0.196	0.738	1.93	0.02	1
0.001	0.01	0.8	0.2	0.5	2	1	2	440	2	440	1760	0.7	0.3	0.7	1147	0.11	973	0.494	0.231	0.726	1.89	0.023	1
0.001	0.01	0.8	0.2	0.5	2	1	2	380	2	380	1520	0.7	0.4	0.6	966	0.1	833	0.442	0.273	0.715	1.84	0.027	1
0.001	0.01	0.8	0.2	0.5	2	1	2	320	2	320	1280	0.7	0.4	0.6	789	0.08	694	0.385	0.321	0.705	1.75	0.032	1

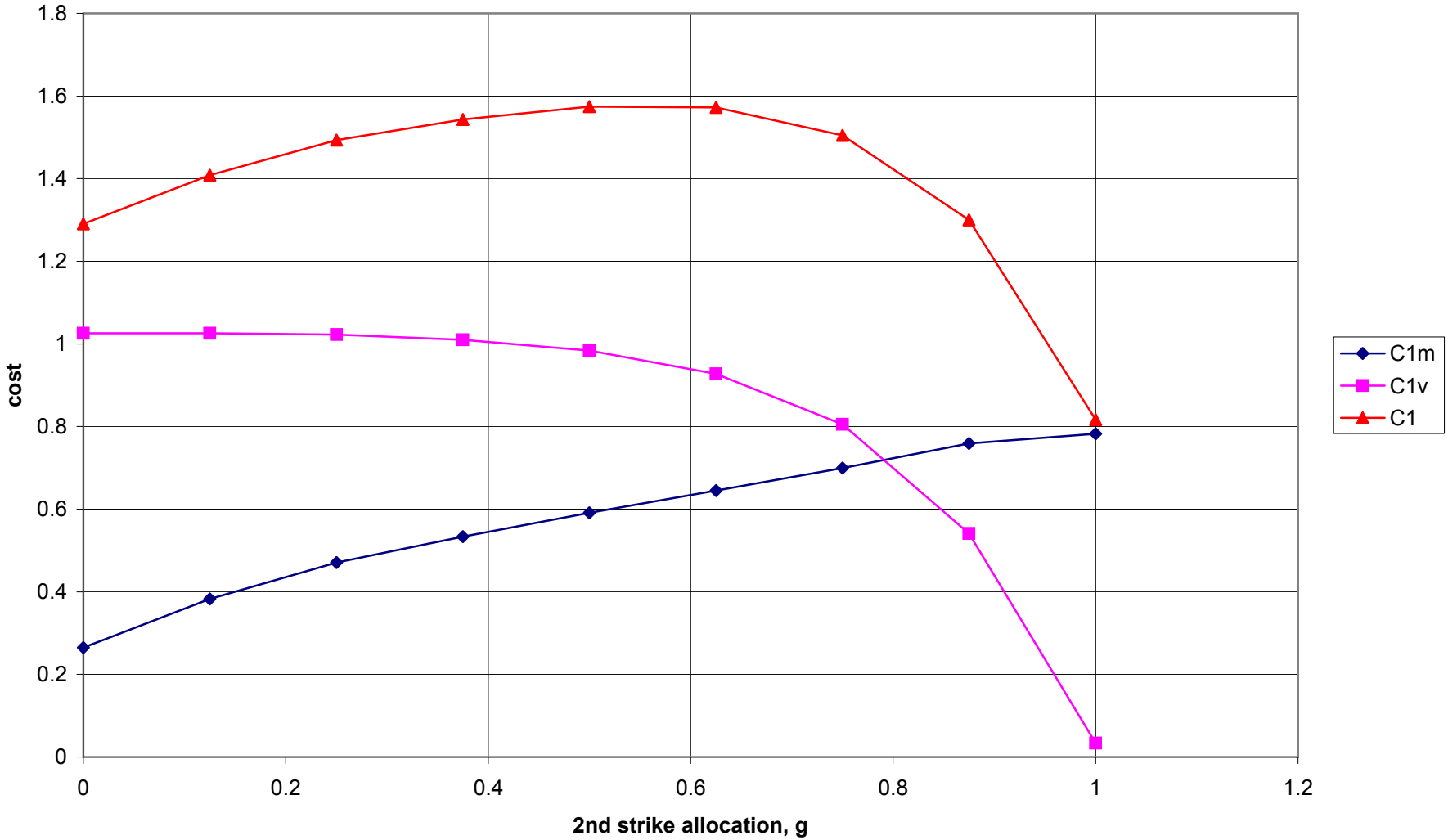

f & h vs g
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
f & h
0
0.2
0.4
0.6
0.8
1
1.2
g
f
h


cost vs g
cost
g
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
0.2
0.4
0.6
0.8
1
1.2
C1sm
C1om
C1m
C1sv
C1ov
C1v
C1

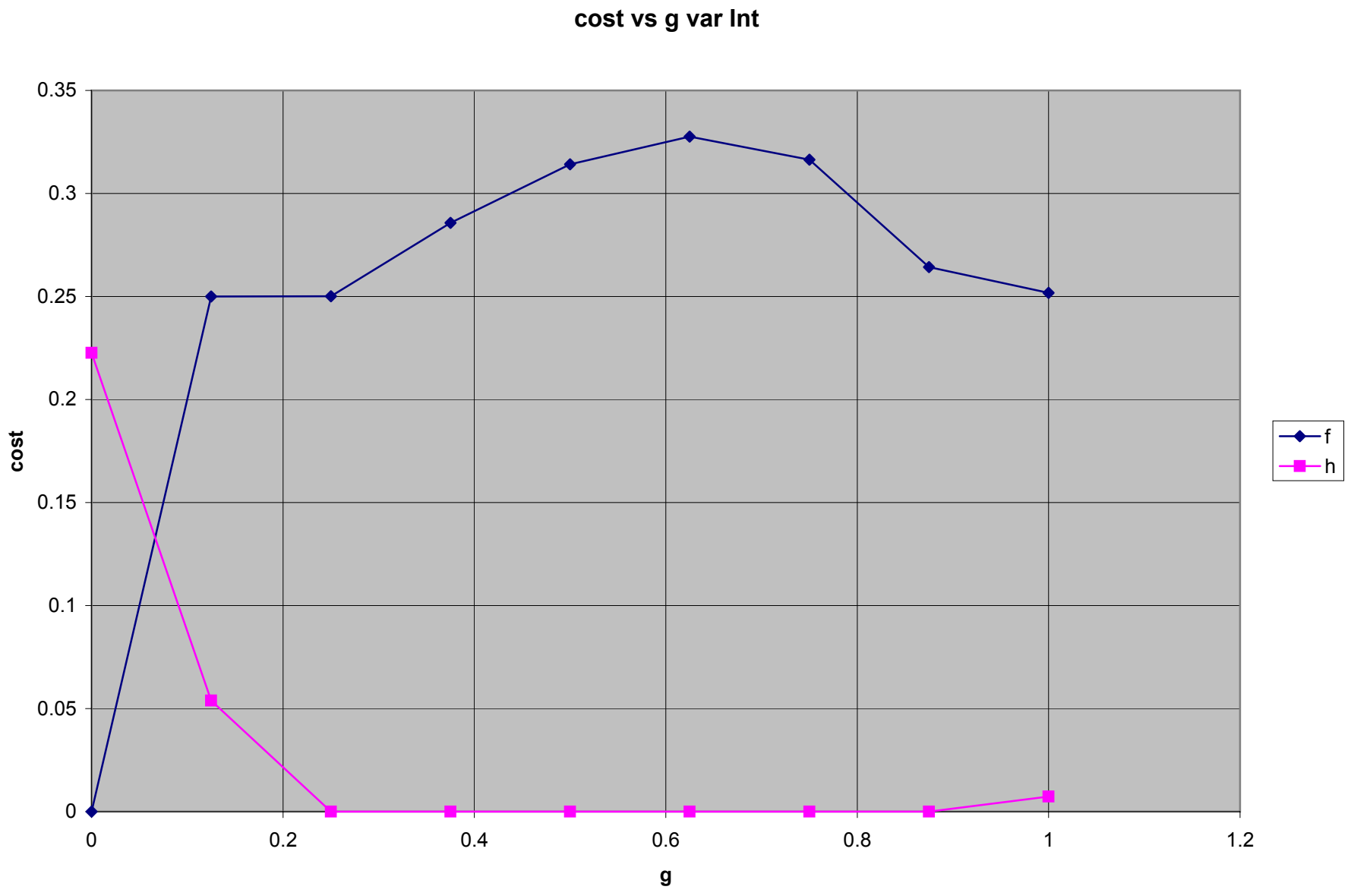

costs vs P preference for attacking military value
costs
g' (P preference for attacking military value)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
C1m
C1v
C1

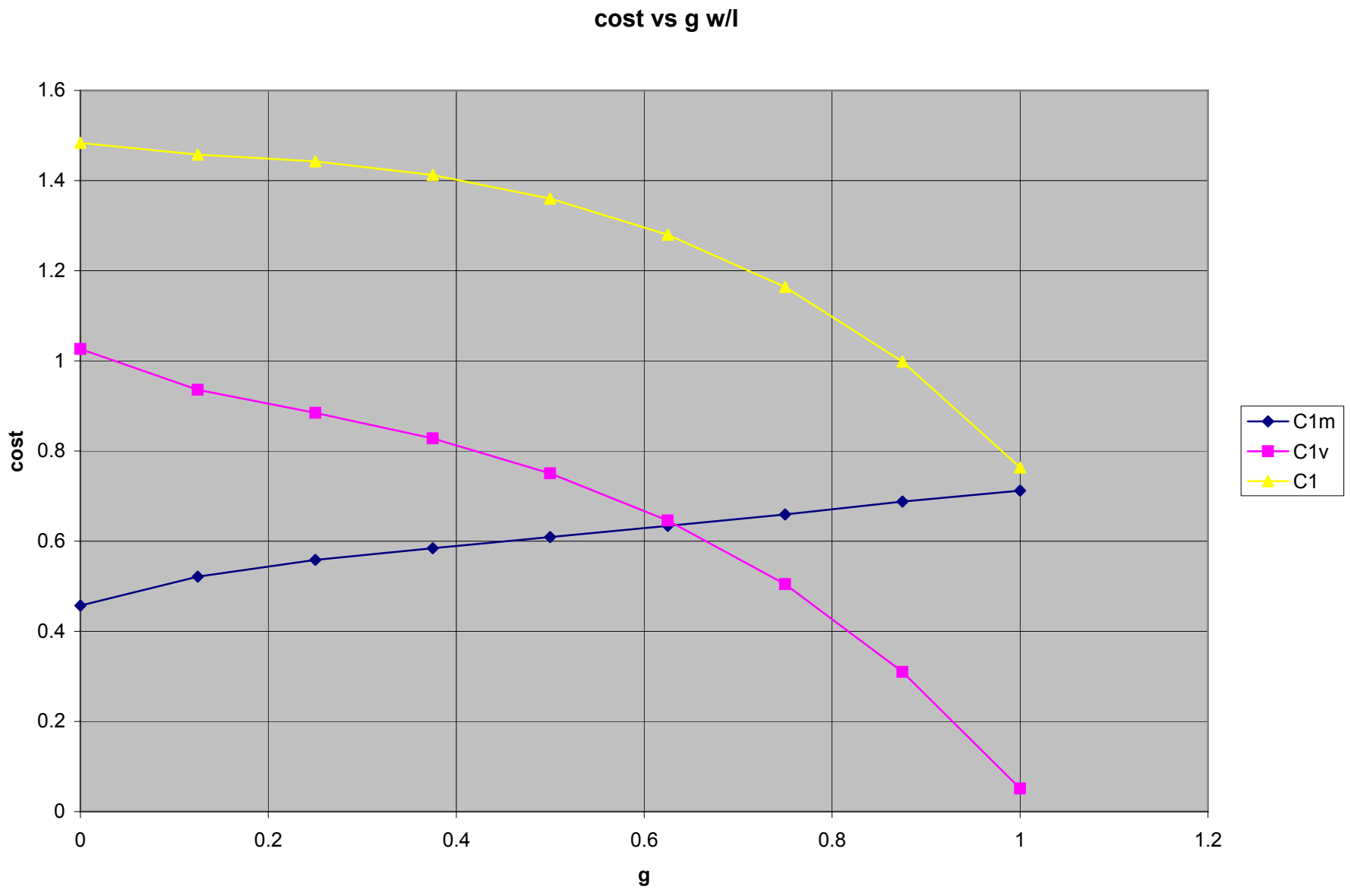
k	v	p	q	L	K	V	m	M	n	N	W	g	f	h	F	Q	S	C1sm	C1om	C1m	C1sv	C1ov	C1v	C1
0.001	0.01	0.8	0.2	0.5	1	0.1	2	250	2	250	1000	0	0	0.8	1000	1	1000	0	0.21	0.215	1	0.021	1.021	1.236
0.001	0.01	0.8	0.2	0.5	1	0.1	2	250	2	250	1000	0.13	0.1	0.8	918	0.59	795	0.09	0.23	0.326	1	0.023	1.022	1.348
0.001	0.01	0.8	0.2	0.5	1	0.1	2	250	2	250	1000	0.25	0.2	0.8	809	0.29	646	0.15	0.26	0.404	0.99	0.026	1.018	1.422
0.001	0.01	0.8	0.2	0.5	1	0.1	2	250	2	250	1000	0.38	0.3	0.8	739	0.19	593	0.2	0.27	0.471	0.98	0.027	1.003	1.474
0.001	0.01	0.8	0.2	0.5	1	0.1	2	250	2	250	1000	0.5	0.3	0.8	686	0.13	566	0.25	0.29	0.532	0.94	0.029	0.97	1.502
0.001	0.01	0.8	0.2	0.5	1	0.1	2	250	2	250	1000	0.63	0.4	0.8	643	0.1	550	0.29	0.3	0.588	0.87	0.03	0.903	1.49
0.001	0.01	0.8	0.2	0.5	1	0.1	2	250	2	250	1000	0.75	0.4	0.8	613	0.08	541	0.33	0.31	0.639	0.74	0.031	0.772	1.411
0.001	0.01	0.8	0.2	0.5	1	0.1	2	250	2	250	1000	0.88	0.4	0.8	609	0.08	540	0.38	0.31	0.683	0.49	0.031	0.522	1.205
0.001	0.01	0.8	0.2	0.5	1	0.1	2	250	2	250	1000	1	0.3	0.8	710	0.15	577	0.44	0.28	0.718	0	0.028	0.028	0.746
																								11.83

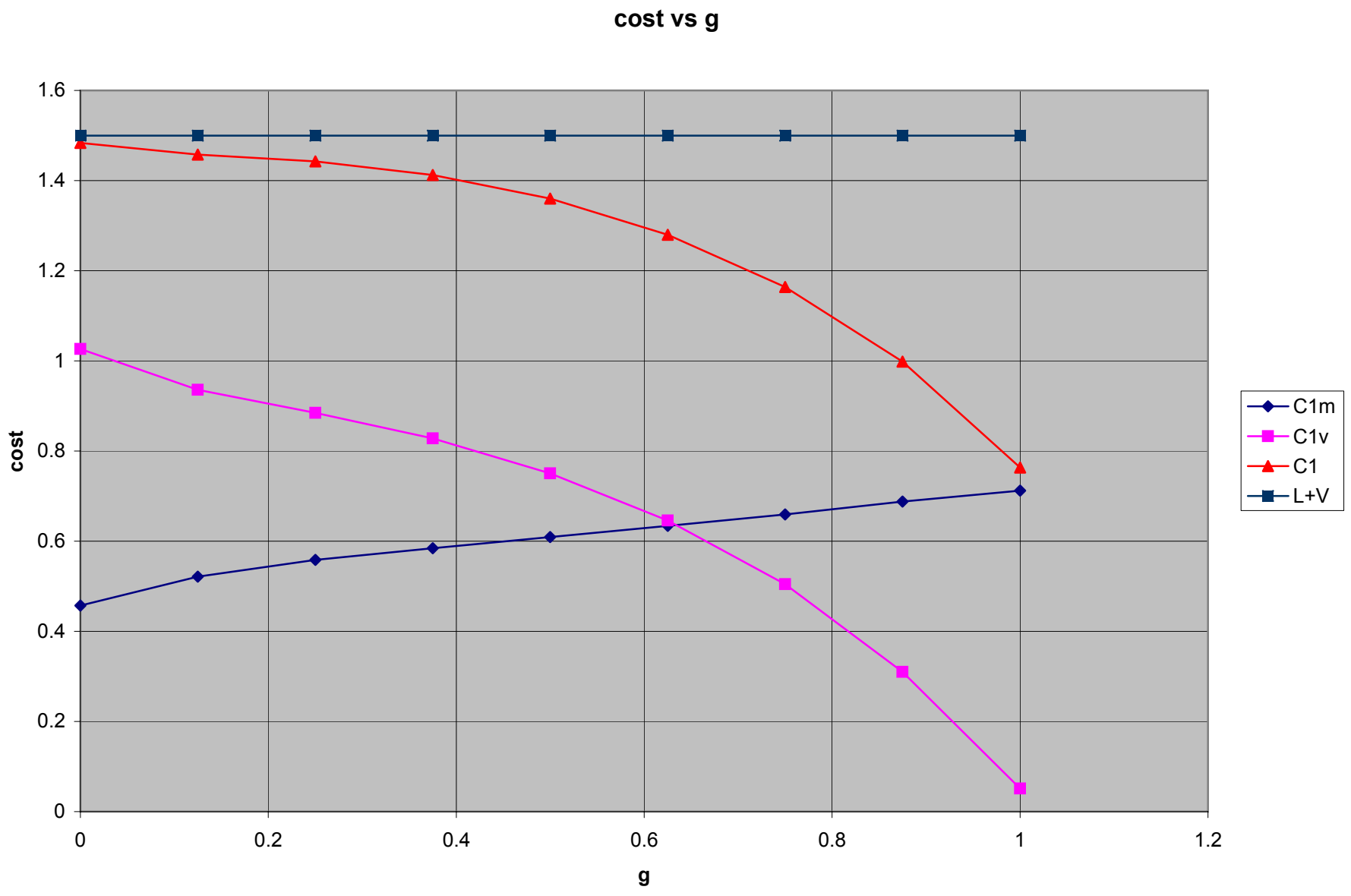
Fig 2. costs vs 2ns strike allocation, g
1,000 weapons



k	v	p	q	L	K	V	m	M	n	N	W	g	f	h	F	r	int r	Q	S	C1ms	C1mo	C1m	C1vs	C1vo	C1v	C1
0.001	0.01	0.8	0.2	0.5	1	1	2	250	2	250	1000	0	0	0.6	1000	0	0	1	1000	0	0.265	0.265	1	0.026	1.026	1.291
0.001	0.01	0.8	0.2	0.5	1	1	2	250	2	250	1000	0.13	0	0.6	1000	0	0	1	1000	0.118	0.265	0.383	1	0.026	1.026	1.408
0.001	0.01	0.8	0.2	0.5	1	1	2	250	2	250	1000	0.25	0.2	0.5	750	1	0	0.2	600	0.139	0.332	0.471	0.99	0.034	1.023	1.493
0.001	0.01	0.8	0.2	0.5	1	1	2	250	2	250	1000	0.38	0.3	0.5	750	1	1	0.2	600	0.201	0.332	0.533	0.98	0.033	1.01	1.543
0.001	0.01	0.8	0.2	0.5	1	1	2	250	2	250	1000	0.5	0.3	0.5	750	1	1	0.2	600	0.259	0.332	0.591	0.95	0.034	0.984	1.575
0.001	0.01	0.8	0.2	0.5	1	1	2	250	2	250	1000	0.63	0.3	0.5	746	1	1	0.2	599	0.312	0.333	0.645	0.89	0.034	0.928	1.573
0.001	0.01	0.8	0.2	0.5	1	1	2	250	2	250	1000	0.75	0.3	0.5	721	1.1	1	0.18	591	0.358	0.341	0.699	0.77	0.034	0.805	1.505
0.001	0.01	0.8	0.2	0.5	1	1	2	250	2	250	1000	0.88	0.4	0.5	633	1.5	1	0.12	562	0.389	0.37	0.759	0.5	0.036	0.541	1.3
0.001	0.01	0.8	0.2	0.5	1	1	2	250	2	250	1000	1	0.3	0.5	750	1	1	0.2	600	0.451	0.332	0.783	0	0.034	0.034	0.816
																										12.5


cost vs g var Int
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
cost
0
0.2
0.4
0.6
0.8
1
1.2
g
f
h


cost vs g w/l
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
cost
0
0.2
0.4
0.6
0.8
1
1.2
g
C1m
C1v
C1


cost vs g
cost
g
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
0.2
0.4
0.6
0.8
1
1.2
C1m
C1v
C1
L+V

k	v	p	q	L	K	V	m	M	n	N	W	I	g	f	h	F	r	int r	Q	S	C1sm	C1om	C1m	C1sv	C1ov	C1v	C1	L+V
0.001	0.01	0.8	0.2	0.5	1	1	2	**100**	2	100	400	**0**	0	0	0.2	400	0	0	1	400	0	0.457	0.46	0.98	0.045	1.03	1.48	1.5
0.001	0.01	0.8	0.2	0.5	1	1	2	100	2	100	400	0	0.13	0.3	0.1	300	1	1	0.2	240	0.03	0.492	0.52	0.88	0.059	0.94	1.46	1.5
0.001	0.01	0.8	0.2	0.5	1	1	2	100	2	100	400	0	0.25	0.3	0	300	1	1	0.2	240	0.058	0.5	0.56	0.83	0.05	0.88	1.44	1.5
0.001	0.01	0.8	0.2	0.5	1	1	2	100	2	100	400	0	0.38	0.3	0	286	1.1	1	0.18	235	0.085	0.5	0.58	0.77	0.057	0.83	1.41	1.5
0.001	0.01	0.8	0.2	0.5	1	1	2	100	2	100	400	0	0.5	0.3	0	274	1.3	1	0.16	232	0.109	0.5	0.61	0.69	0.064	0.75	1.36	1.5
0.001	0.01	0.8	0.2	0.5	1	1	2	100	2	100	400	0	0.63	0.3	0	269	1.3	1	0.15	230	0.134	0.5	0.63	0.58	0.068	0.65	1.28	1.5
0.001	0.01	0.8	0.2	0.5	1	1	2	100	2	100	400	0	0.75	0.3	0	273	1.3	1	0.16	232	0.159	0.5	0.66	0.44	0.065	0.5	1.16	1.5
0.001	0.01	0.8	0.2	0.5	1	1	2	100	2	100	400	0	0.88	0.3	0	294	1.1	1	0.19	238	0.188	0.5	0.69	0.26	0.053	0.31	1	1.5
0.001	0.01	0.8	0.2	0.5	1	1	2	100	2	100	400	0	1	0.3	0	299	1	1	0.2	240	0.213	0.499	0.71	0	0.051	0.05	0.76	1.5
																											11.4	

k	v	p	q	L	K	V	m	M	n	N	W	I	g	f	h	F	r	int r	Q	S	C1sm	C1om	C1m	C1sv	C1ov	C1v	C1	L+V	kbar	g opt	vbar	h
0.001	0	0.8	0	0.5	1	0.5	2	**100**	2	100	400	**0**	0	0	0.39	400	0	0	1	400	0	0.428	0.43	0.98	0.044	1.03	1.45	1	-0.006	0.39	-0	0.39
0.001	0	0.8	0	0.5	1	0.5	2	100	2	100	400	0	0.13	0.2	0.23	300	1	0	0.2	240	0.03	0.467	0.5	0.88	0.049	0.93	1.42	1	-0.01	0.04	-0	0.21
0.001	0	0.8	0	0.5	1	0.5	2	100	2	100	400	0	0.25	0.3	0.16	276	1.2	1	0.16	232	0.056	0.478	0.53	0.82	0.05	0.87	1.41	1	-0.01	0.01	-0	0.15
0.001	0	0.8	0	0.5	1	0.5	2	100	2	100	400	0	0.38	0.4	0.13	250	1.5	1	0.12	224	0.081	0.484	0.56	0.75	0.057	0.81	1.37	1	-0.01	-0	-0	0.07
0.001	0	0.8	0	0.5	1	0.5	2	100	2	100	400	0	0.5	0.5	0.02	207	1.9	1	0.05	210	0.1	0.498	0.6	0.65	0.066	0.72	1.31	1	-0.011	-0.1	-0	-0.1
0.001	0	0.8	0	0.5	1	0.5	2	100	2	100	400	0	0.63	0.5	0	207	1.9	1	0.05	210	0.123	0.5	0.62	0.55	0.063	0.61	1.23	1	-0.011	-0.1	-0	-0.1
0.001	0	0.8	0	0.5	1	0.5	2	100	2	100	400	0	0.75	0.5	0	205	1.9	1	0.05	210	0.146	0.5	0.65	0.41	0.064	0.47	1.12	1	-0.011	-0.1	-0	-0.11
0.001	0	0.8	0	0.5	1	0.5	2	100	2	100	400	0	0.88	0.3	0.22	294	1.1	1	0.19	238	0.188	0.469	0.66	0.26	0.051	0.31	0.96	1	-0.01	0.03	-0	0.2
0.001	0	0.8	0	0.5	1	0.5	2	100	2	100	400	0	1	0.3	0.2	300	1	1	0.2	240	0.213	0.471	0.68	0	0.045	0.05	0.73	1	-0.01	0.04	-0	0.21

Fig. 3. Allocations f, g, & h vs total forces, W

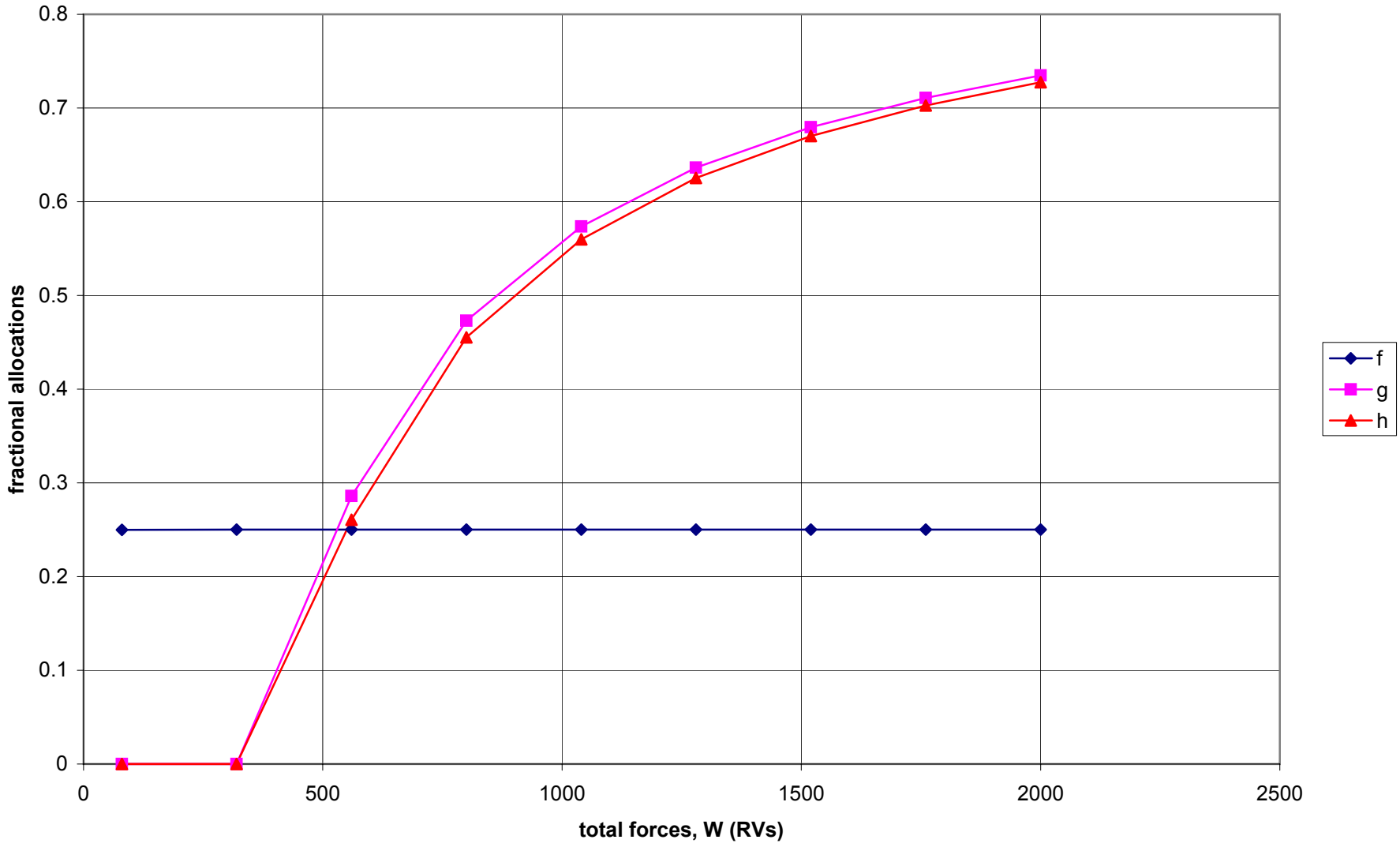


Fig. 4. weapons on high value targets vs total forces

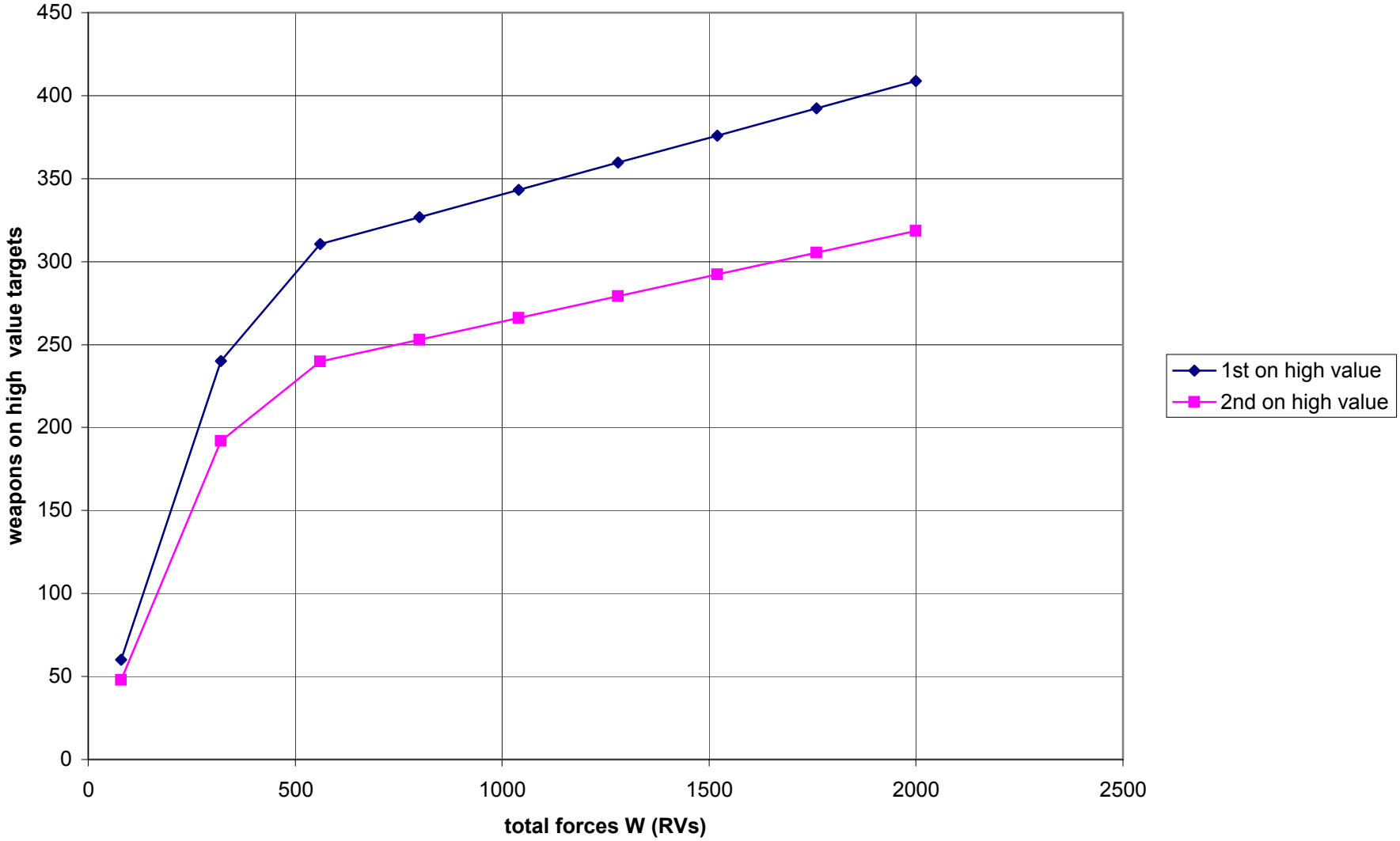


Fig. 5. costs vs total forces W

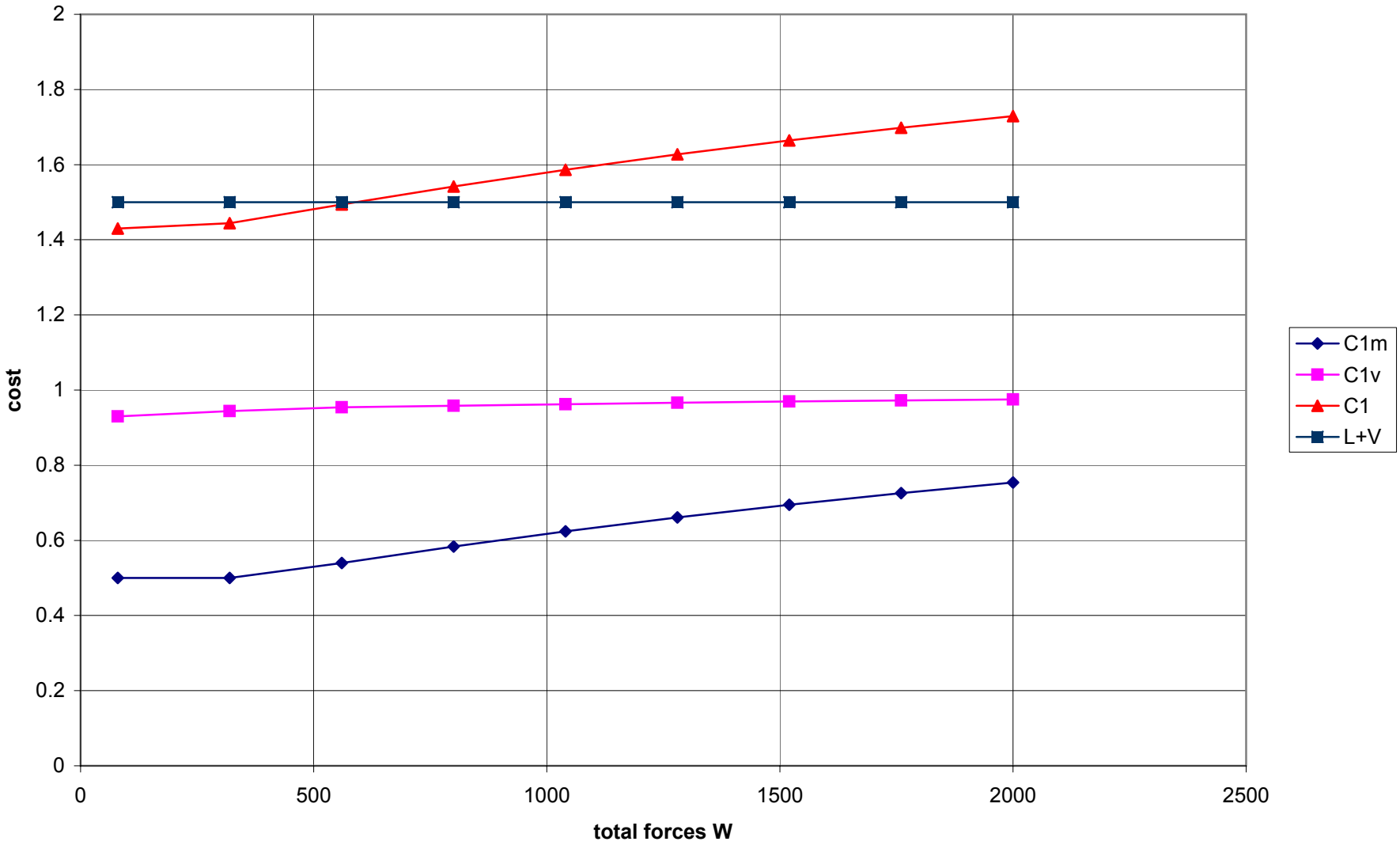
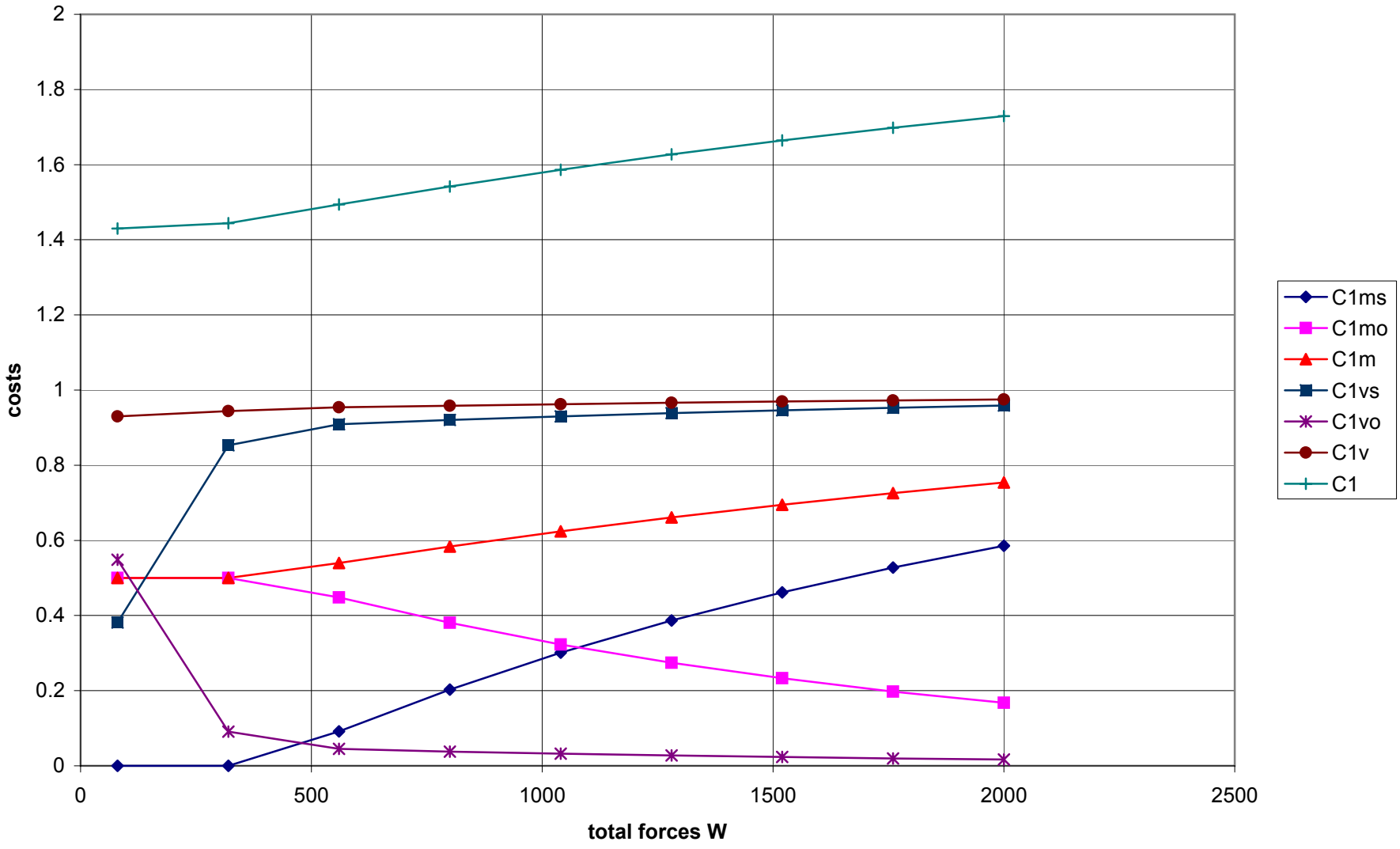
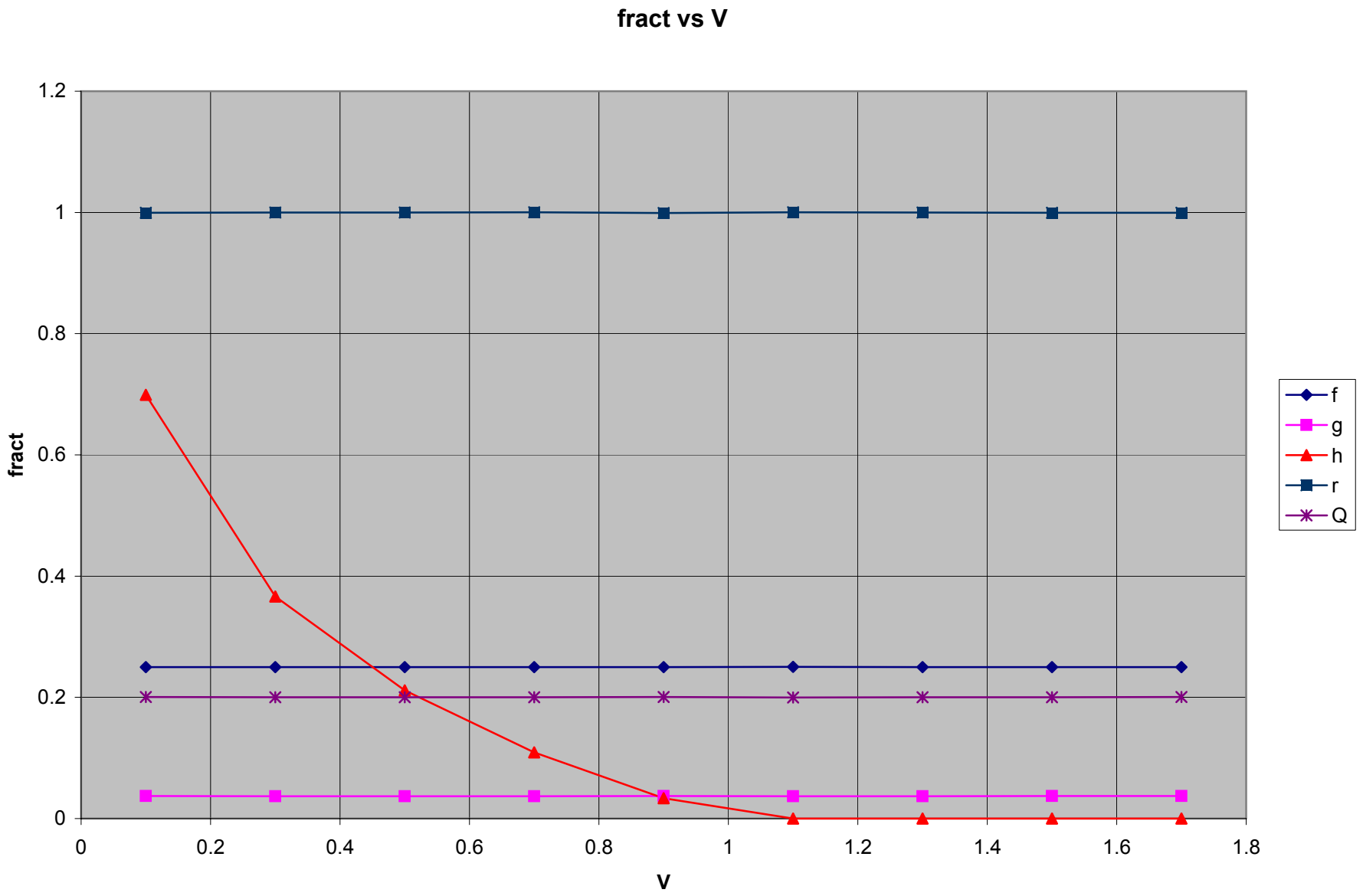


Fig. 6. costs vs W



k	v	p	q	L	K	V	m	M	n	N	W	I	f	kbar	g	vbar	h	F	r	int	Q	S	C1ms	C1mo	C1m	C1vs	C1vo	C1v	C1	L+V	1st on h	2nd on high value
0.001	0	0.8	0	0.5	1	1	2	500	2	500	2000	**0**	0.3	-0.002	0.73	-0.002	0.73	1500	1	1	0.2	1200	0.59	0.17	0.75	0.96	0.02	0.98	1.73	1.5	408.7	318
0.001	0	0.8	0	0.5	1	1	2	440	2	440	1760	0	0.3	-0.002	0.71	-0.002	0.7	1320	1	1	0.2	1056	0.53	0.2	0.73	0.95	0.02	0.97	1.7	1.5	392.3	305
0.001	0	0.8	0	0.5	1	1	2	380	2	380	1520	0	0.3	-0.003	0.68	-0.003	0.67	1140	1	1	0.2	912	0.46	0.23	0.69	0.95	0.02	0.97	1.66	1.5	376	292
0.001	0	0.8	0	0.5	1	1	2	320	2	320	1280	0	0.3	-0.003	0.64	-0.003	0.63	960	1	1	0.2	768	0.39	0.27	0.66	0.94	0.03	0.97	1.63	1.5	359.6	279
0.001	0	0.8	0	0.5	1	1	2	260	2	260	1040	0	0.3	-0.004	0.57	-0.004	0.56	780	1	1	0.2	624	0.3	0.32	0.62	0.93	0.03	0.96	1.59	1.5	343.2	266
0.001	0	0.8	0	0.5	1	1	2	200	2	200	800	0	0.3	-0.005	0.47	-0.005	0.46	600	1	1	0.2	480	0.2	0.38	0.58	0.92	0.04	0.96	1.54	1.5	326.9	253
0.001	0	0.8	0	0.5	1	1	2	140	2	140	560	0	0.3	-0.007	0.29	-0.007	0.26	420	1	1	0.2	336	0.09	0.45	0.54	0.91	0.04	0.95	1.49	1.5	310.5	240
0.001	0	0.8	0	0.5	1	1	2	80	2	80	320	0	0.3	-0.012	0	-0.012	0	240	1	1	0.2	192	0	0.5	0.5	0.85	0.09	0.94	1.44	1.5	240	192
0.001	0	0.8	0	0.5	1	1	2	20	2	20	80	0	0.2	-0.048	0	-0.05	0	60	1	0	0.2	48	0	0.5	0.5	0.38	0.55	0.93	1.43	1.5	60	48
																													14.2			


fract vs V
fract
V
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1
0.8
0.6
0.4
0.2
0
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
f
g
h
r
Q

Fig. . costs vs first strike high value preference V

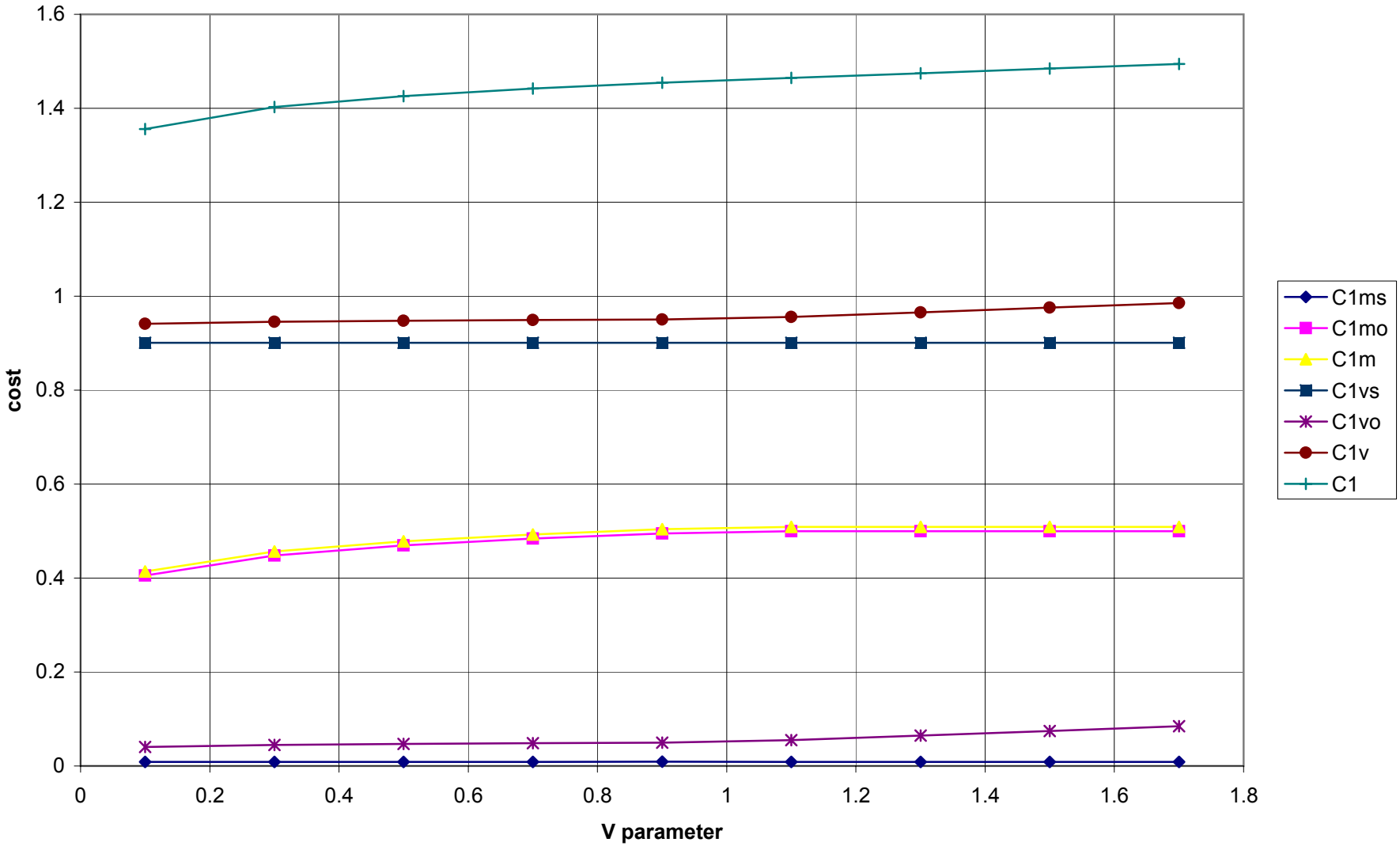
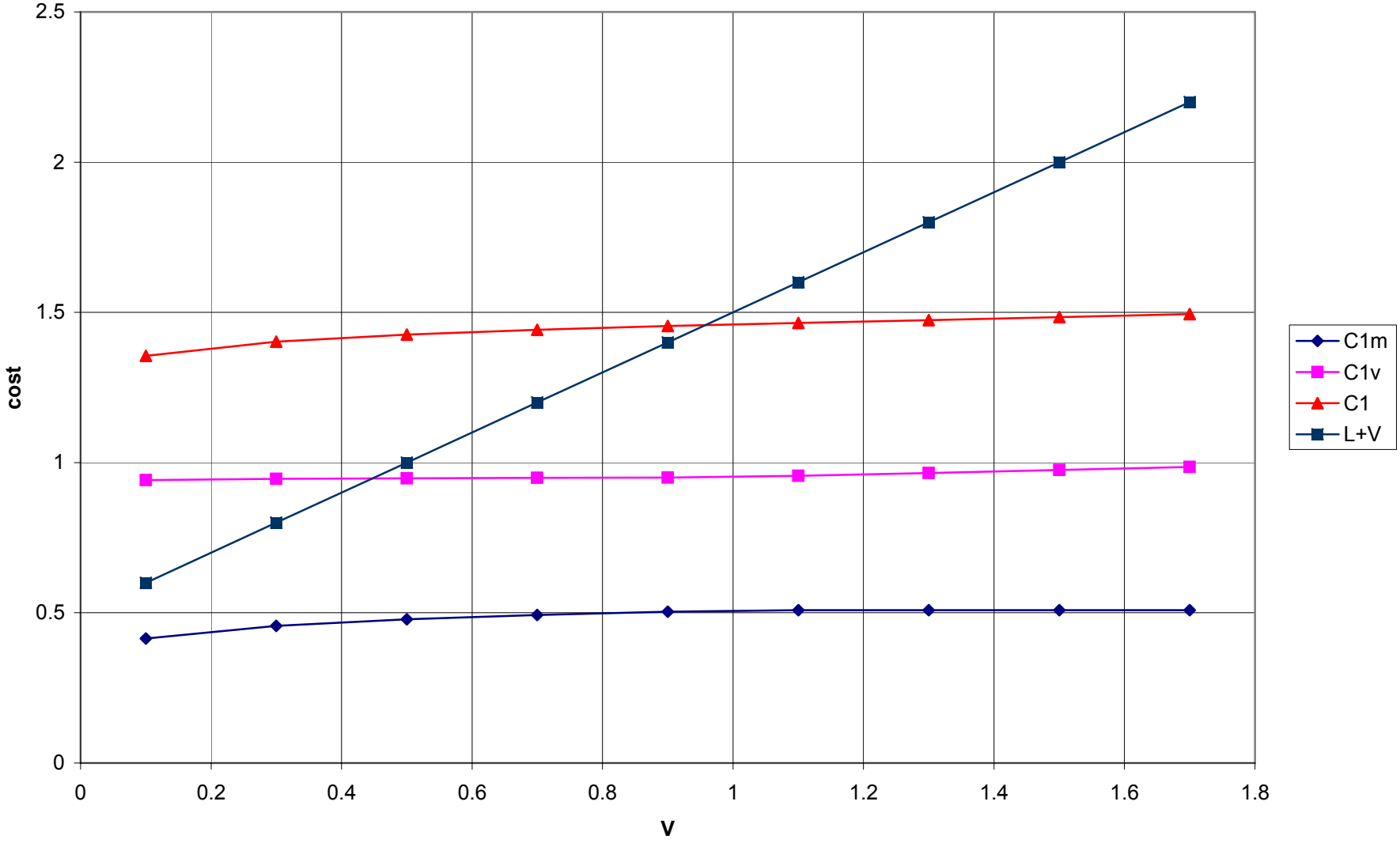


Fig.7. costs vs 1st strike high value parameter V



k	v	p	q	L	K	V	m	M	n	N	W	I	f	kbar	g	vbar	h	F	r	int r	Q	S	C1ms	C1mc	C1m	C1vs	C1vo	C1v	C1	L+V
0.001	0.01	0.8	0	0.5	1	0.1	2	100	2	100	400	**0**	0.2	-0.01	0.04	-0.002	0.7	300	1	0	0.2	240	0.01	0.41	0.41	0.9	0.04	0.94	1.36	0.6
0.001	0.01	0.8	0	0.5	1	0.3	2	100	2	100	400	0	0.2	-0.01	0.04	-0.006	0.37	300	1	0	0.2	240	0.01	0.45	0.46	0.9	0.04	0.95	1.4	0.8
0.001	0.01	0.8	0	0.5	1	0.5	2	100	2	100	400	0	0.2	-0.01	0.04	-0.008	0.21	300	1	0	0.2	240	0.01	0.47	0.48	0.9	0.05	0.95	1.43	1
0.001	0.01	0.8	0	0.5	1	0.7	2	100	2	100	400	0	0.3	-0.01	0.04	-0.009	0.11	300	1	1	0.2	240	0.01	0.48	0.49	0.9	0.05	0.95	1.44	1.2
0.001	0.01	0.8	0	0.5	1	0.9	2	100	2	100	400	0	0.2	-0.01	0.04	-0.01	0.03	300	1	0	0.2	240	0.01	0.5	0.5	0.9	0.05	0.95	1.45	1.4
0.001	0.01	0.8	0	0.5	1	1.1	2	100	2	100	400	0	0.3	-0.01	0.04	-0.01	0	300	1	1	0.2	240	0.01	0.5	0.51	0.9	0.05	0.96	1.46	1.6
0.001	0.01	0.8	0	0.5	1	1.3	2	100	2	100	400	0	0.2	-0.01	0.04	-0.011	0	300	1	0	0.2	240	0.01	0.5	0.51	0.9	0.06	0.97	1.47	1.8
0.001	0.01	0.8	0	0.5	1	1.5	2	100	2	100	400	0	0.2	-0.01	0.04	-0.011	0	300	1	0	0.2	240	0.01	0.5	0.51	0.9	0.07	0.98	1.48	2
0.001	0.01	0.8	0	0.5	1	1.7	2	100	2	100	400	0	0.2	-0.01	0.04	-0.012	0	300	1	0	0.2	240	0.01	0.5	0.51	0.9	0.08	0.99	1.49	2.2

Fig. 8. Fractional allocations vs 2nd strike high value parameter K
W = 1,000 weapons

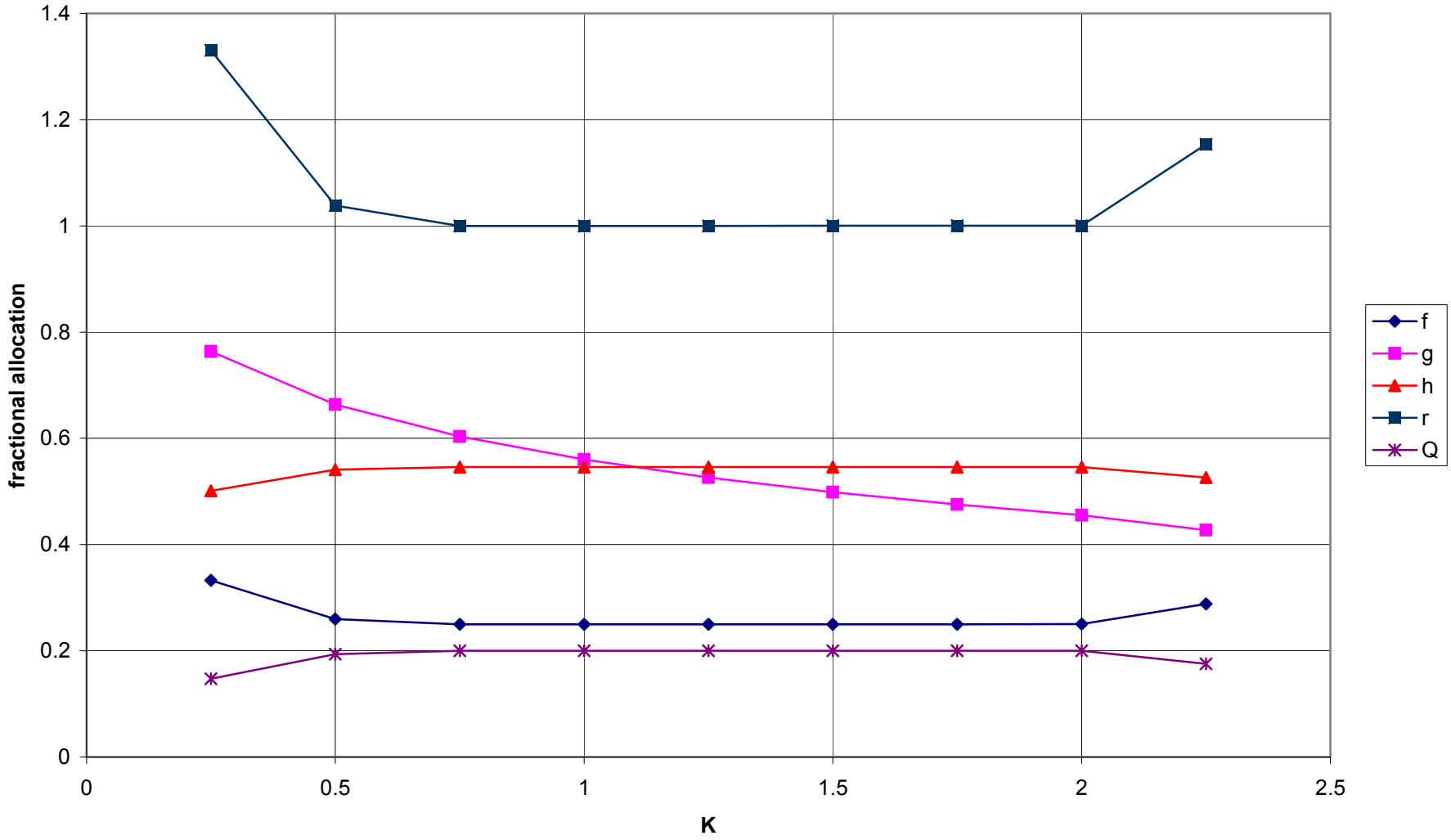
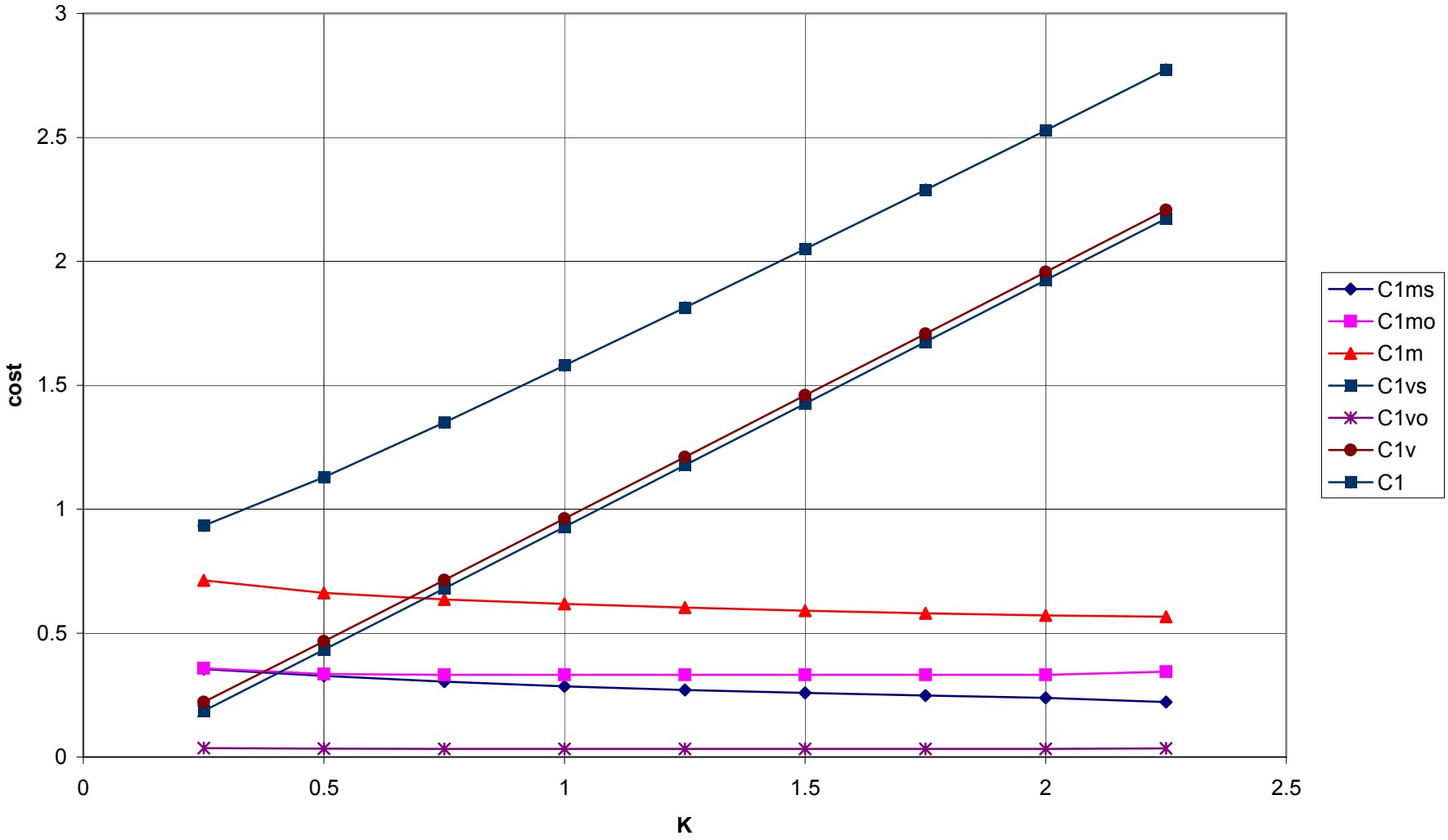


Fig. 9. cost vs 2nd strike high value parameter K
W = 1,000 weapons



k	v	p	q	L	K	V	m	M	n	N	W	I	f	kbar	g	vbar	h	F	r	int	Q	S	C1ms	C1mo	C1m	C1vs	C1vo	C1v	C1	L+V
0.001	0	0.8	0	0.5	0.3	1	2	250	2	250	1000	**0**	0.3	-0.002	0.76	-0.0045	0.5	667	1.3	1	0.15	574	0.35	0.36	0.71	0.19	0.04	0.22	0.93	1.5
0.001	0	0.8	0	0.5	0.5	1	2	250	2	250	1000	0	0.3	-0.003	0.66	-0.004	0.54	740	1	1	0.19	597	0.33	0.33	0.66	0.43	0.03	0.47	1.13	1.5
0.001	0	0.8	0	0.5	0.8	1	2	250	2	250	1000	0	0.2	-0.003	0.6	-0.004	0.55	750	1	0	0.2	600	0.3	0.33	0.64	0.68	0.03	0.71	1.35	1.5
0.001	0	0.8	0	0.5	1	1	2	250	2	250	1000	0	0.3	-0.004	0.56	-0.004	0.55	750	1	1	0.2	600	0.29	0.33	0.62	0.93	0.03	0.96	1.58	1.5
0.001	0	0.8	0	0.5	1.3	1	2	250	2	250	1000	0	0.3	-0.004	0.53	-0.004	0.55	750	1	1	0.2	600	0.27	0.33	0.6	1.18	0.03	1.21	1.81	1.5
0.001	0	0.8	0	0.5	1.5	1	2	250	2	250	1000	0	0.3	-0.005	0.5	-0.004	0.55	750	1	1	0.2	600	0.26	0.33	0.59	1.43	0.03	1.46	2.05	1.5
0.001	0	0.8	0	0.5	1.8	1	2	250	2	250	1000	0	0.3	-0.005	0.48	-0.004	0.55	750	1	1	0.2	600	0.25	0.33	0.58	1.67	0.03	1.71	2.29	1.5
0.001	0	0.8	0	0.5	2	1	2	250	2	250	1000	0	0.3	-0.005	0.46	-0.004	0.55	750	1	1	0.2	600	0.24	0.33	0.57	1.92	0.03	1.96	2.53	1.5
0.001	0	0.8	0	0.5	2.3	1	2	250	2	250	1000	0	0.3	-0.005	0.43	-0.0042	0.53	712	1.2	1	0.18	588	0.22	0.34	0.57	2.17	0.03	2.21	2.77	1.5
																													16.4	

Fig. 10. allocations vs interceptors

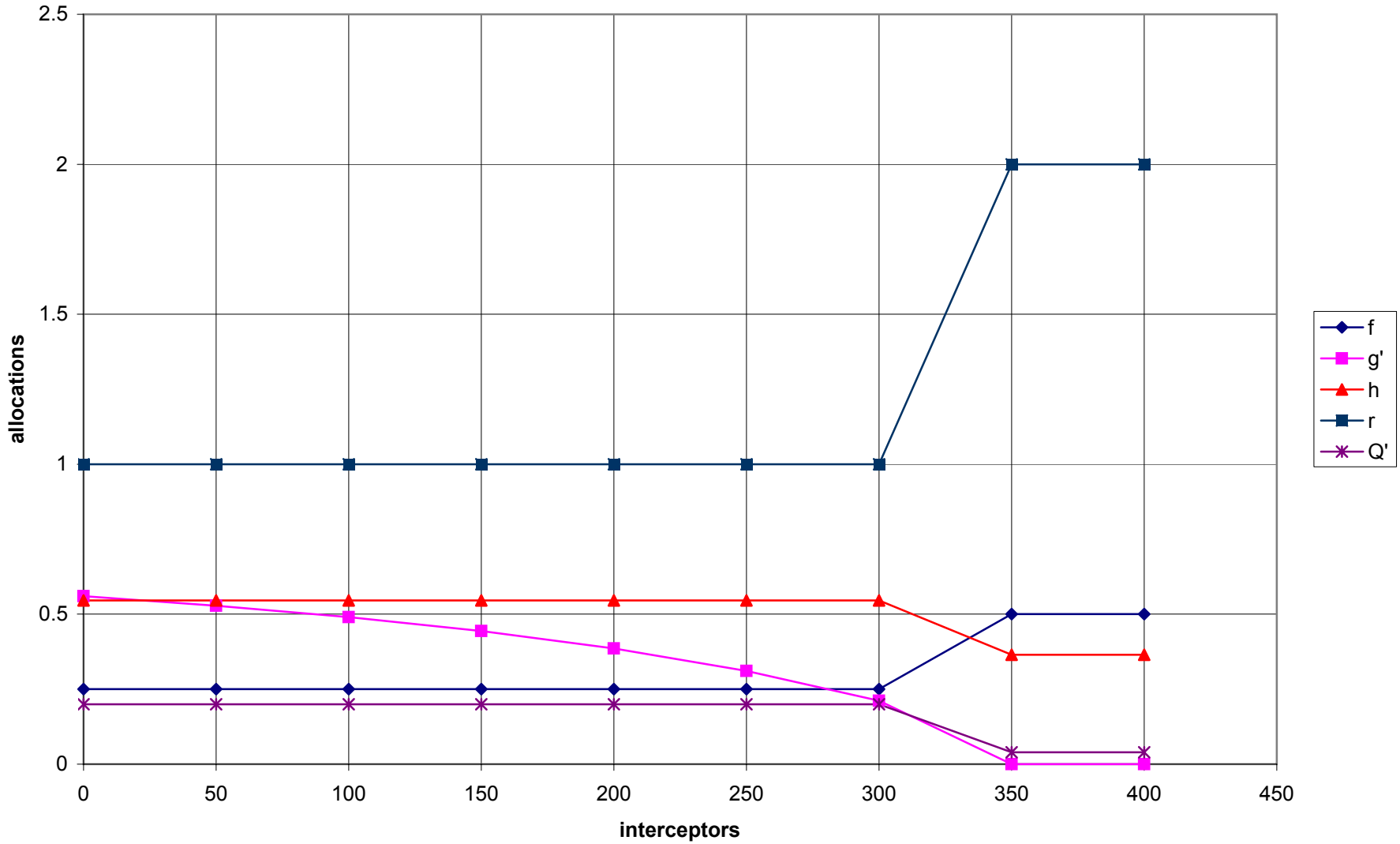


Fig. 11. costs vs Interceptors

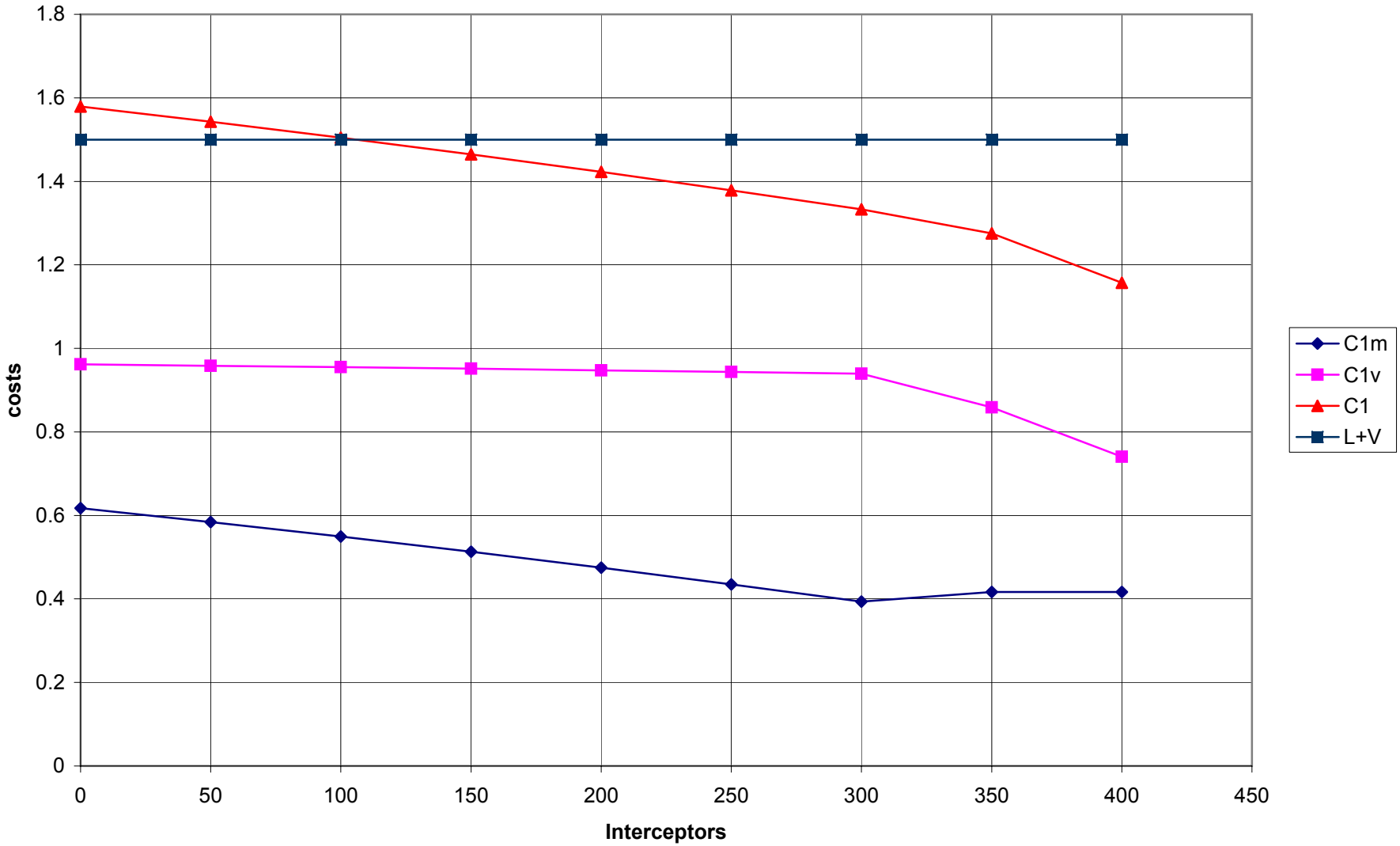
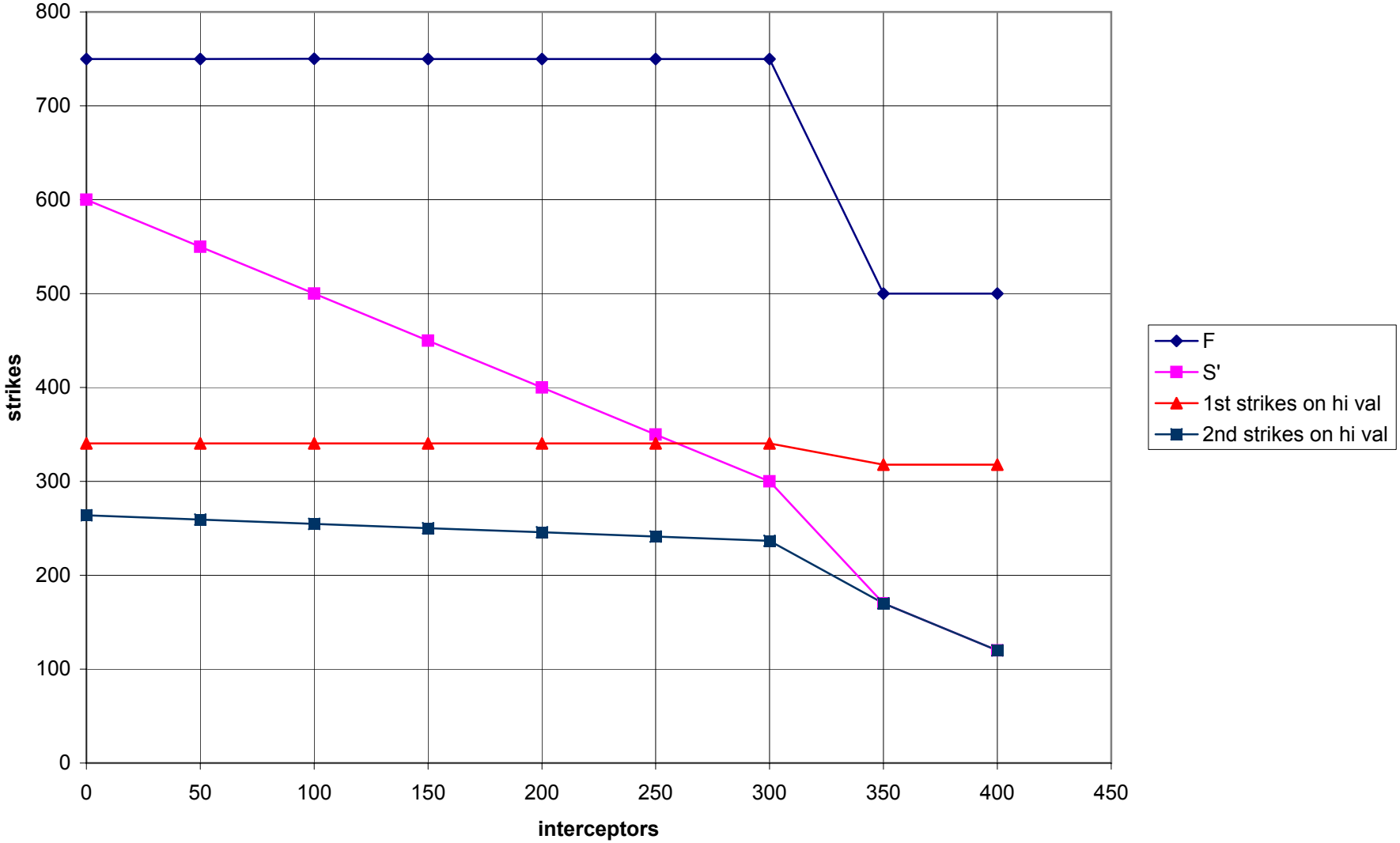
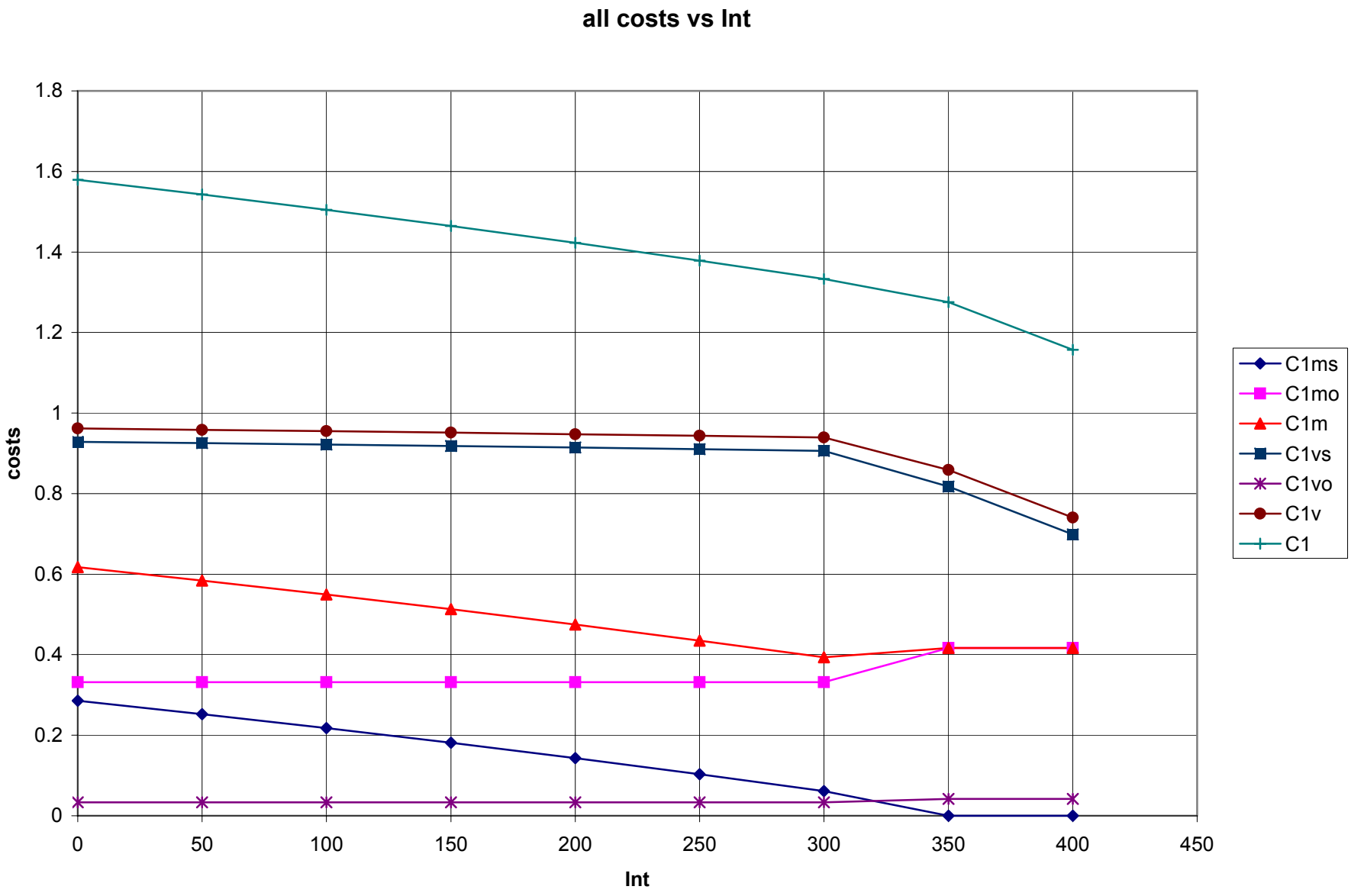


Fig. 12. strikes on high value targets vs interceptors




all costs vs Int
costs
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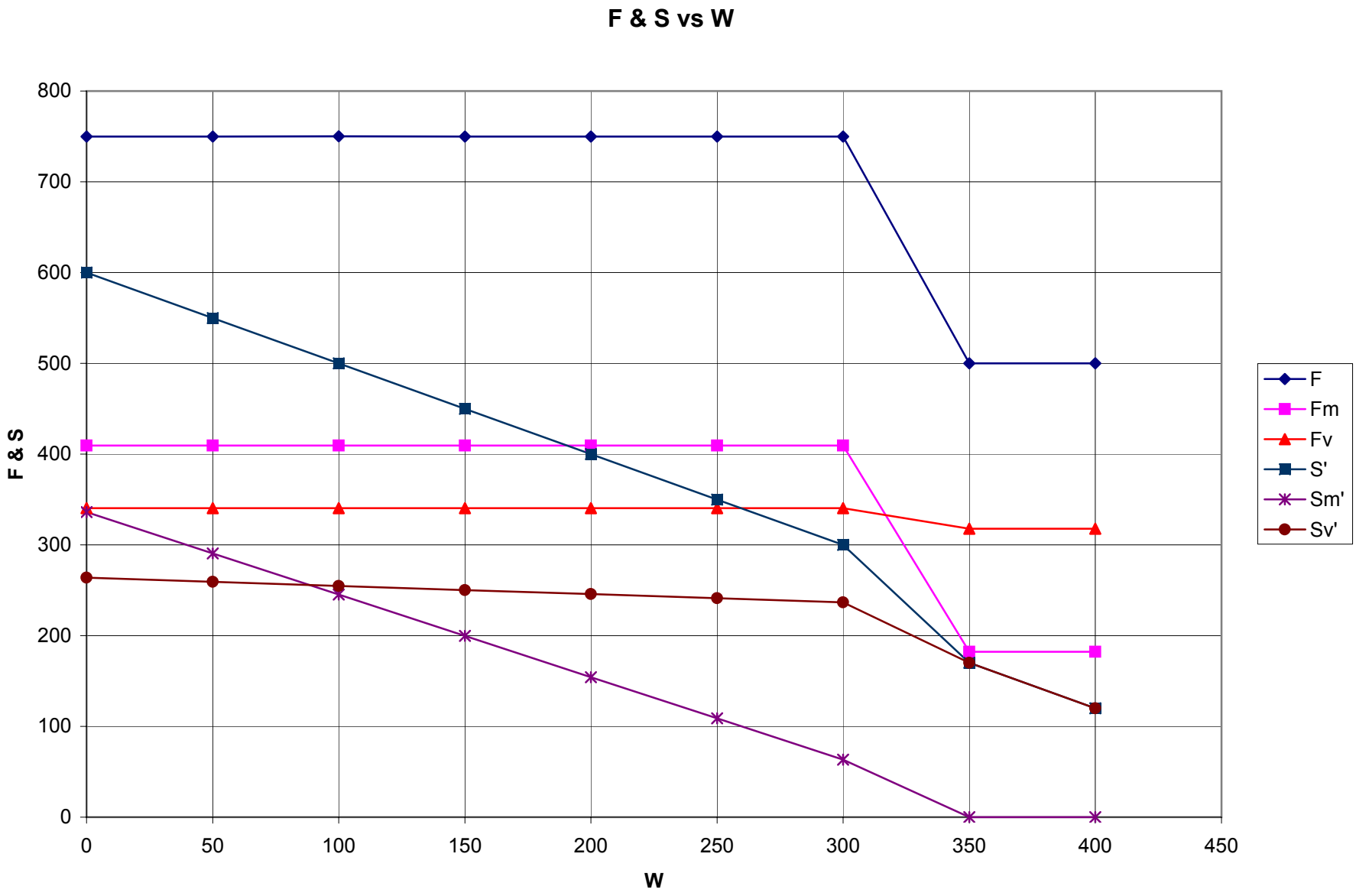
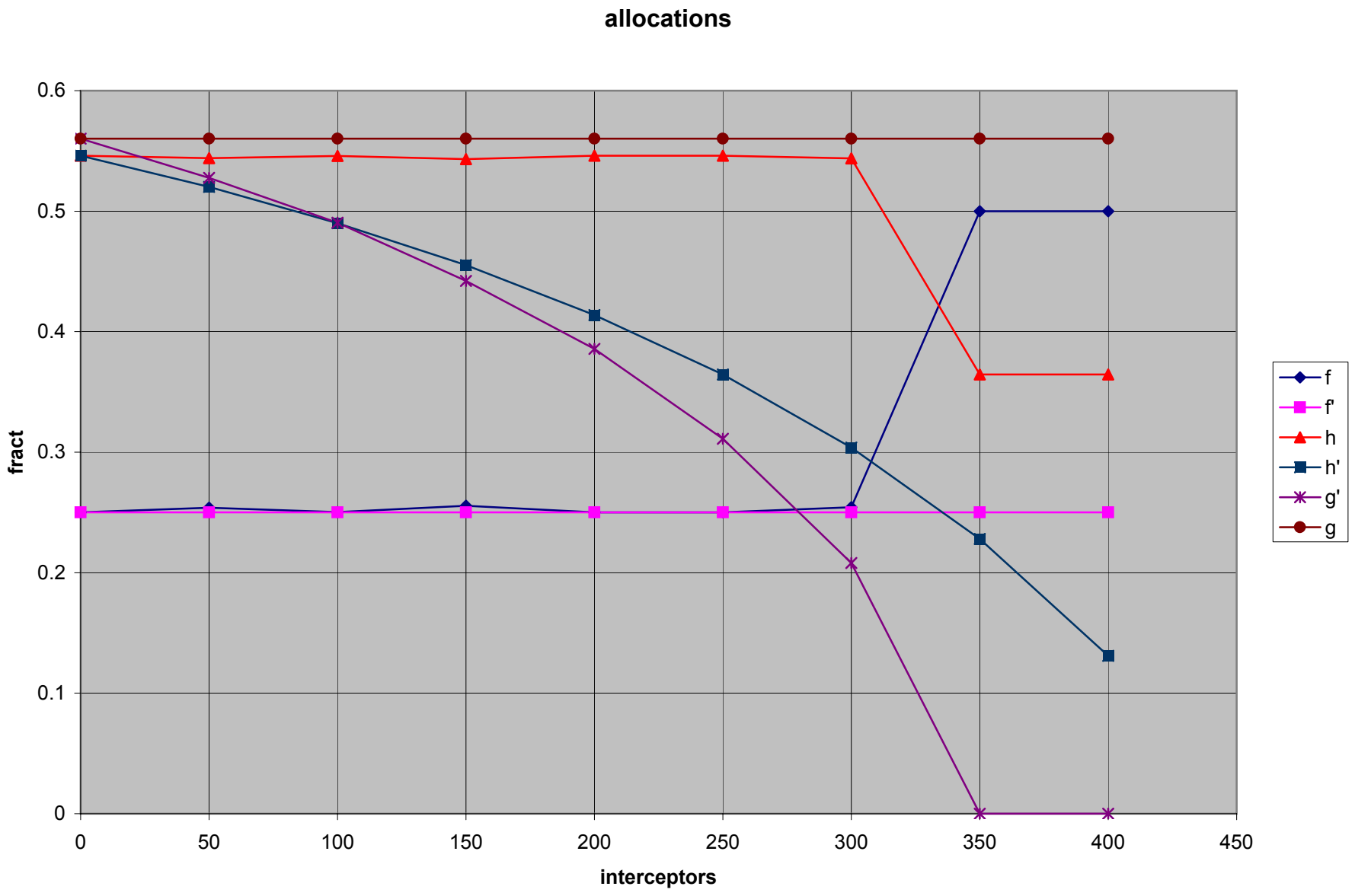
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
50
100
150
200
250
300
350
400
450
C1ms
C1mo
C1m
C1vs
C1vo
C1v
C1

k	k'	v	v'	p	q	L	K	V	m	M	n	N	W	I	f	g1	g'	h1	h	F	r	int	Q'	S'	C1ms	C1mc	C1m	C1vs	C1vo	C1v	C1	L+V	1st s	2nd strikes on hi val
0.001	0.001	0.01	0.01	0.8	0	0.5	1	1	2	250	2	250	1000	0	0.25	-0	0.56	-0	0.55	750	1	1	0.2	600	0.29	0.33	0.62	0.93	0.03	0.96	1.58	1.5	341	263.8713248
0.001	0.001	0.01	0.01	0.8	0	0.5	1	1	2	250	2	250	1000	50	0.25	-0	0.53	-0	0.55	750	1	1	0.2	550	0.25	0.33	0.58	0.93	0.03	0.96	1.54	1.5	341	259.3259164
0.001	0.001	0.01	0.01	0.8	0	0.5	1	1	2	250	2	250	1000	100	0.25	-0	0.49	-0	0.55	750	1	0	0.2	500	0.22	0.33	0.55	0.92	0.03	0.95	1.5	1.5	341	254.7804696
0.001	0.001	0.01	0.01	0.8	0	0.5	1	1	2	250	2	250	1000	150	0.25	-0	0.44	-0	0.55	750	1	1	0.2	450	0.18	0.33	0.51	0.92	0.03	0.95	1.46	1.5	341	250.2349093
0.001	0.001	0.01	0.01	0.8	0	0.5	1	1	2	250	2	250	1000	200	0.25	-0	0.39	-0	0.55	750	1	1	0.2	400	0.14	0.33	0.47	0.91	0.03	0.95	1.42	1.5	341	245.6894955
0.001	0.001	0.01	0.01	0.8	0	0.5	1	1	2	250	2	250	1000	250	0.25	-0	0.31	-0	0.55	750	1	1	0.2	350	0.1	0.33	0.44	0.91	0.03	0.94	1.38	1.5	341	241.1430002
0.001	0.001	0.01	0.01	0.8	0	0.5	1	1	2	250	2	250	1000	300	0.25	-0	0.21	-0	0.55	750	1	1	0.2	300	0.06	0.33	0.39	0.91	0.03	0.94	1.33	1.5	341	236.5984683
0.001	0.001	0.01	0.01	0.8	0	0.5	1	1	2	250	2	250	1000	350	0.5	-0	0	-0	0.36	500	2	1	0.04	170	0	0.42	0.42	0.82	0.04	0.86	1.28	1.5	318	170.0000855
0.001	0.001	0.01	0.01	0.8	0	0.5	1	1	2	250	2	250	1000	400	0.5	-0	0	-0	0.36	500	2	1	0.04	120	0	0.42	0.42	0.7	0.04	0.74	1.16	1.5	318	120.0000001
																															12.7			


F & S vs W
800
700
600
500
400
300
200
100
0
F & S
0
50
100
150
200
250
300
350
400
450
W
F
Fm
Fv
S'
Sm'
Sv'

p	q	m	M	n	N	W	I	k'	v'	q'	m'	M'	n'	N'	W'	I'	f	F	h	h	r	Q'	S'	g	g'	k	k'	v	v'	L	L'	K	V	K'	V'	Fm	Fv	Sm'	Sv'	C1ms	C1mo	C1m	C1vs	C1vo	C1v	C1	C2ms'	C2mo	C2m'	C2vs'	C2vo'	C2v'	C2'
1	0	2	250	2	250	1000	0	0	0	0.2	2	250	2	250	1000	0	0.3	750	0.5	1	0.2	600	#	0.6	0	0	0	0	0.5	0.5	1	1	1	1	409	341	336	264	0.29	0.33	0.62	0.93	0.03	0.96	1.58	0.34	0.36	0.69	0.97	0.07	1.04	1.73
1	0	2	250	2	250	1000	50	0	0	0.2	2	250	2	250	1000	0	0.3	750	0.5	1	0.2	550	#	0.5	0	0	0	0	0.5	0.5	1	1	1	1	409	341	291	259	0.25	0.33	0.58	0.93	0.03	0.96	1.54	0.34	0.37	0.71	0.97	0.07	1.04	1.75
1	0	2	250	2	250	1000	100	0	0	0.2	2	250	2	250	1000	0	0.2	750	0.5	1	0.2	500	#	0.5	0	0	0	0	0.5	0.5	1	1	1	1	409	341	245	255	0.22	0.33	0.55	0.92	0.03	0.95	1.5	0.34	0.39	0.73	0.97	0.08	1.05	1.77
1	0	2	250	2	250	1000	150	0	0	0.2	2	250	2	250	1000	0	0.3	750	0.5	1	0.2	450	#	0.4	0	0	0	0	0.5	0.5	1	1	1	1	409	341	200	250	0.18	0.33	0.51	0.92	0.03	0.95	1.46	0.34	0.41	0.75	0.97	0.08	1.05	1.79
1	0	2	250	2	250	1000	200	0	0	0.2	2	250	2	250	1000	0	0.3	750	0.5	1	0.2	400	#	0.4	0	0	0	0	0.5	0.5	1	1	1	1	409	341	154	246	0.14	0.33	0.47	0.91	0.03	0.95	1.42	0.34	0.43	0.76	0.97	0.09	1.05	1.82
1	0	2	250	2	250	1000	250	0	0	0.2	2	250	2	250	1000	0	0.3	750	0.5	1	0.2	350	#	0.3	0	0	0	0	0.5	0.5	1	1	1	1	409	341	109	241	0.1	0.33	0.44	0.91	0.03	0.94	1.38	0.34	0.45	0.78	0.97	0.09	1.06	1.84
1	0	2	250	2	250	1000	300	0	0	0.2	2	250	2	250	1000	0	0.3	750	0.5	1	0.2	300	#	0.2	0	0	0	0	0.5	0.5	1	1	1	1	409	341	63	237	0.06	0.33	0.39	0.91	0.03	0.94	1.33	0.34	0.47	0.81	0.97	0.09	1.06	1.87
1	0	2	250	2	250	1000	350	0	0	0.2	2	250	2	250	1000	0	0.5	500	0.4	2	0	170	#	0	0	0	0	0	0.5	0.5	1	1	1	1	182	318	0	170	0	0.42	0.42	0.82	0.04	0.86	1.28	0.17	0.5	0.67	0.96	0.18	1.14	1.81
1	0	2	250	2	250	1000	400	0	0	0.2	2	250	2	250	1000	0	0.5	500	0.4	2	0	120	#	0	0	0	0	0	0.5	0.5	1	1	1	1	182	318	0	120	0	0.42	0.42	0.7	0.04	0.74	1.16	0.17	0.5	0.67	0.96	0.3	1.26	1.93

12.7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interceptors
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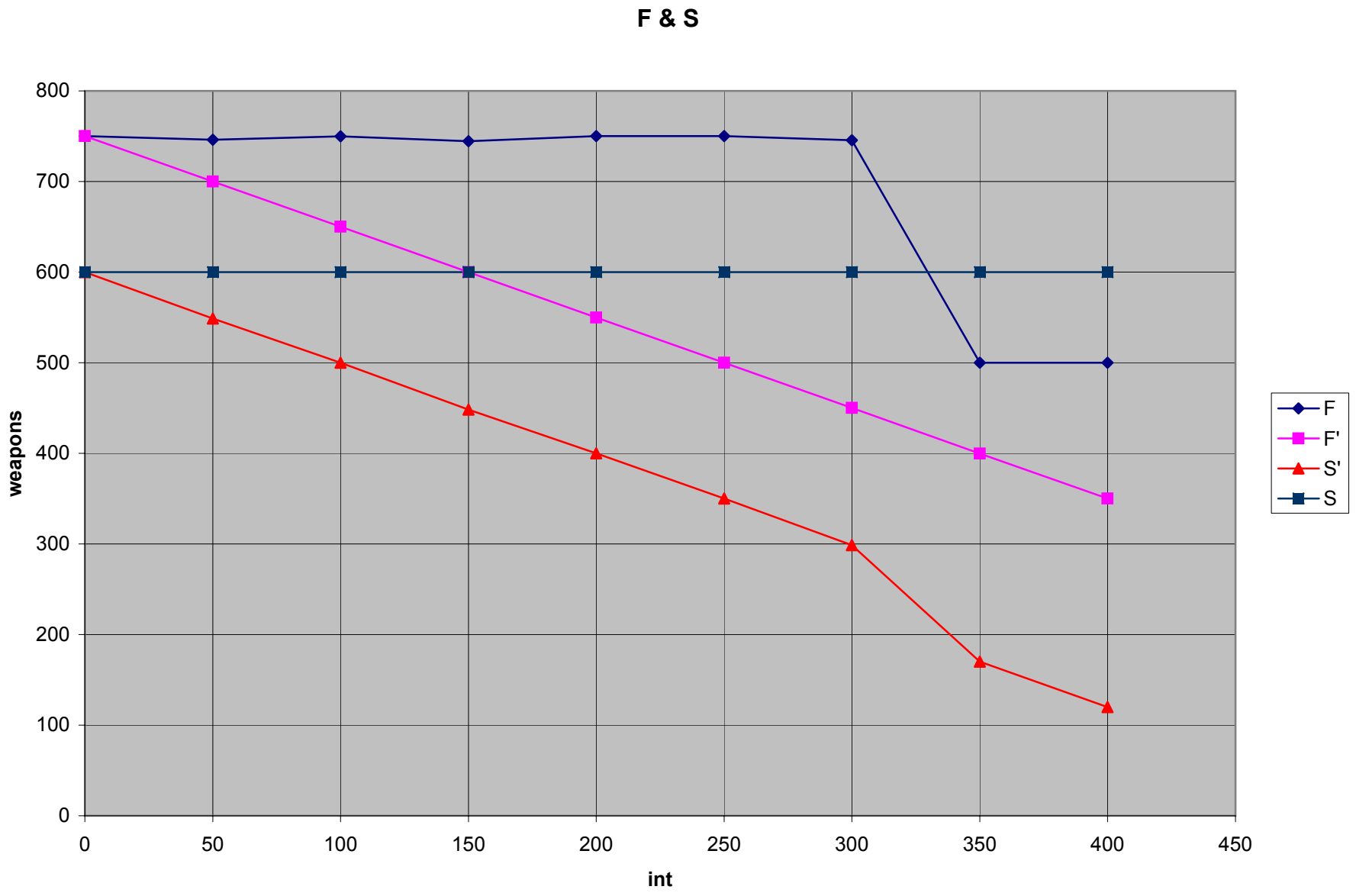
450
f
f'
h
h'
g'
g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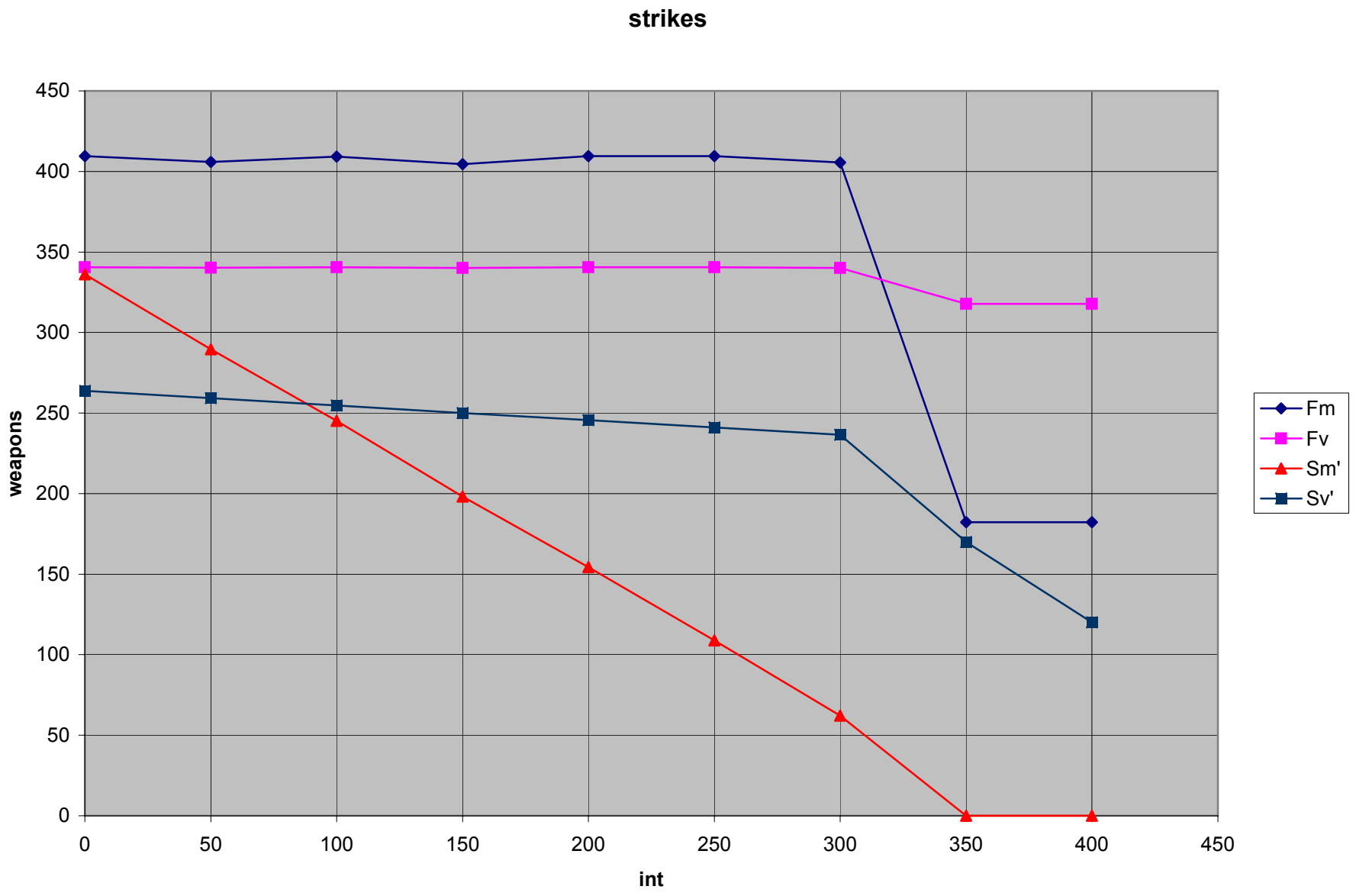
int
F
F'
S'
S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weapons
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400
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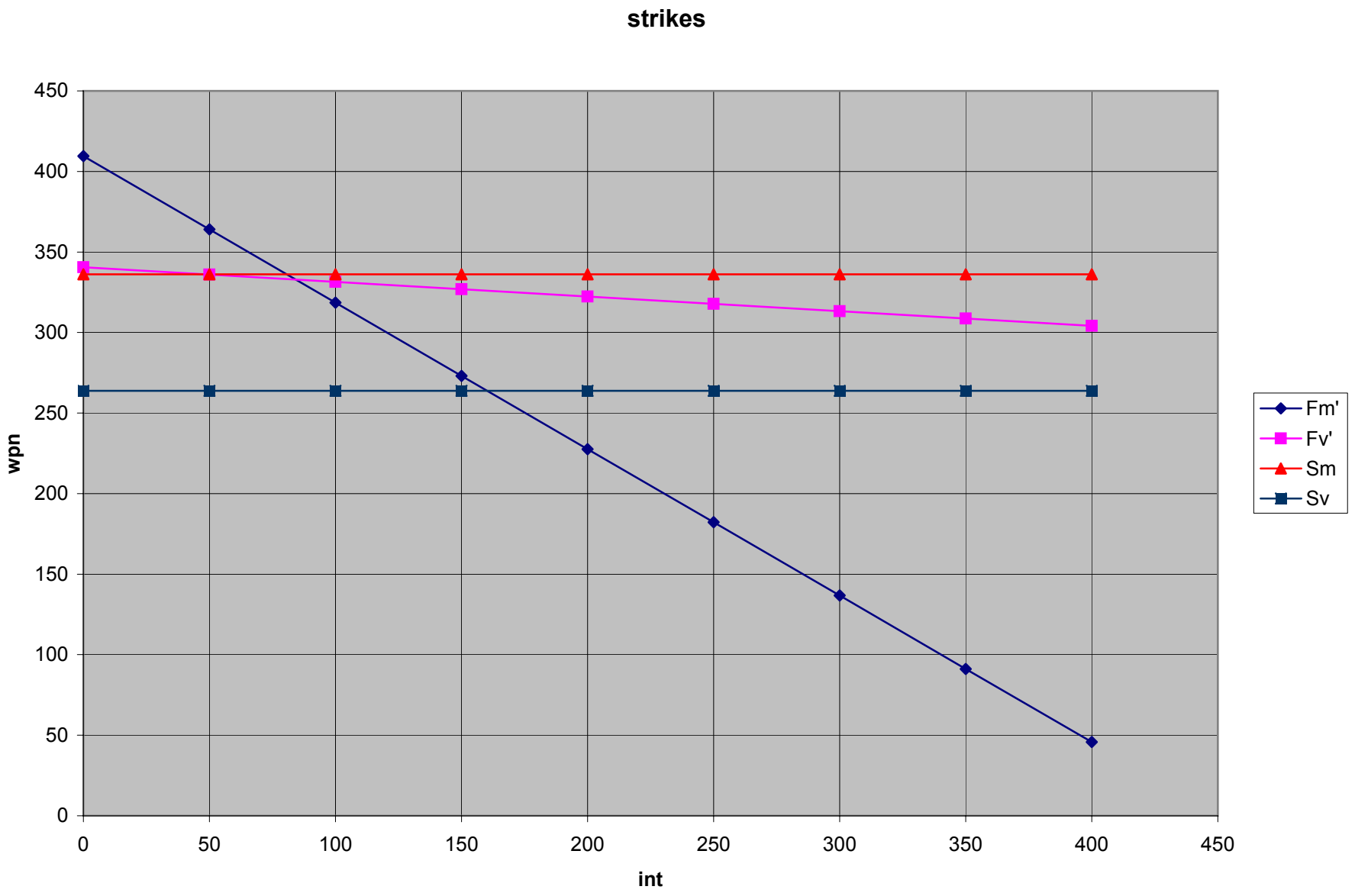
Fm
Fv
Sm'
Sv'


strikes
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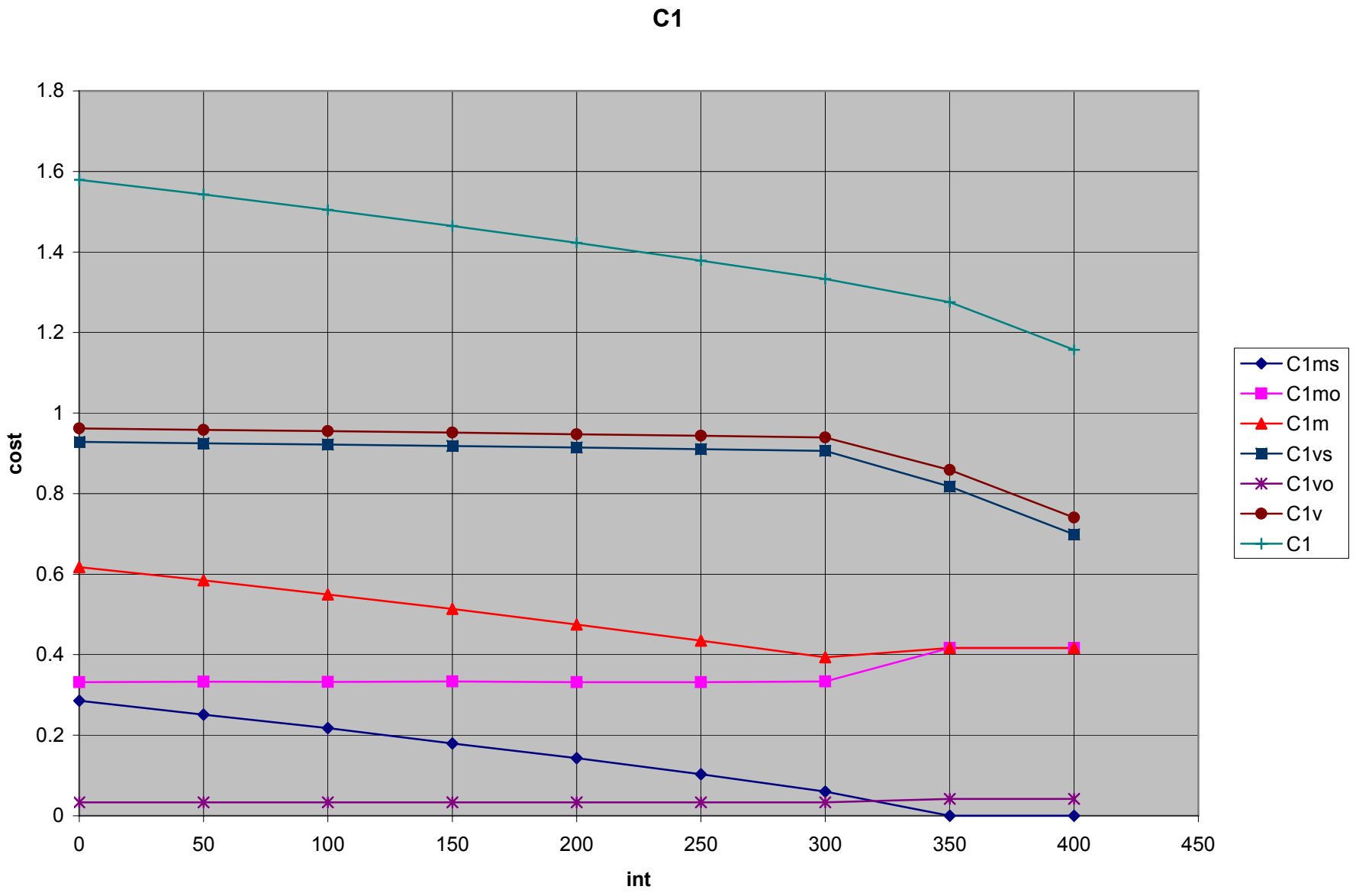
Fm'
Fv'
Sm
Sv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1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
cost
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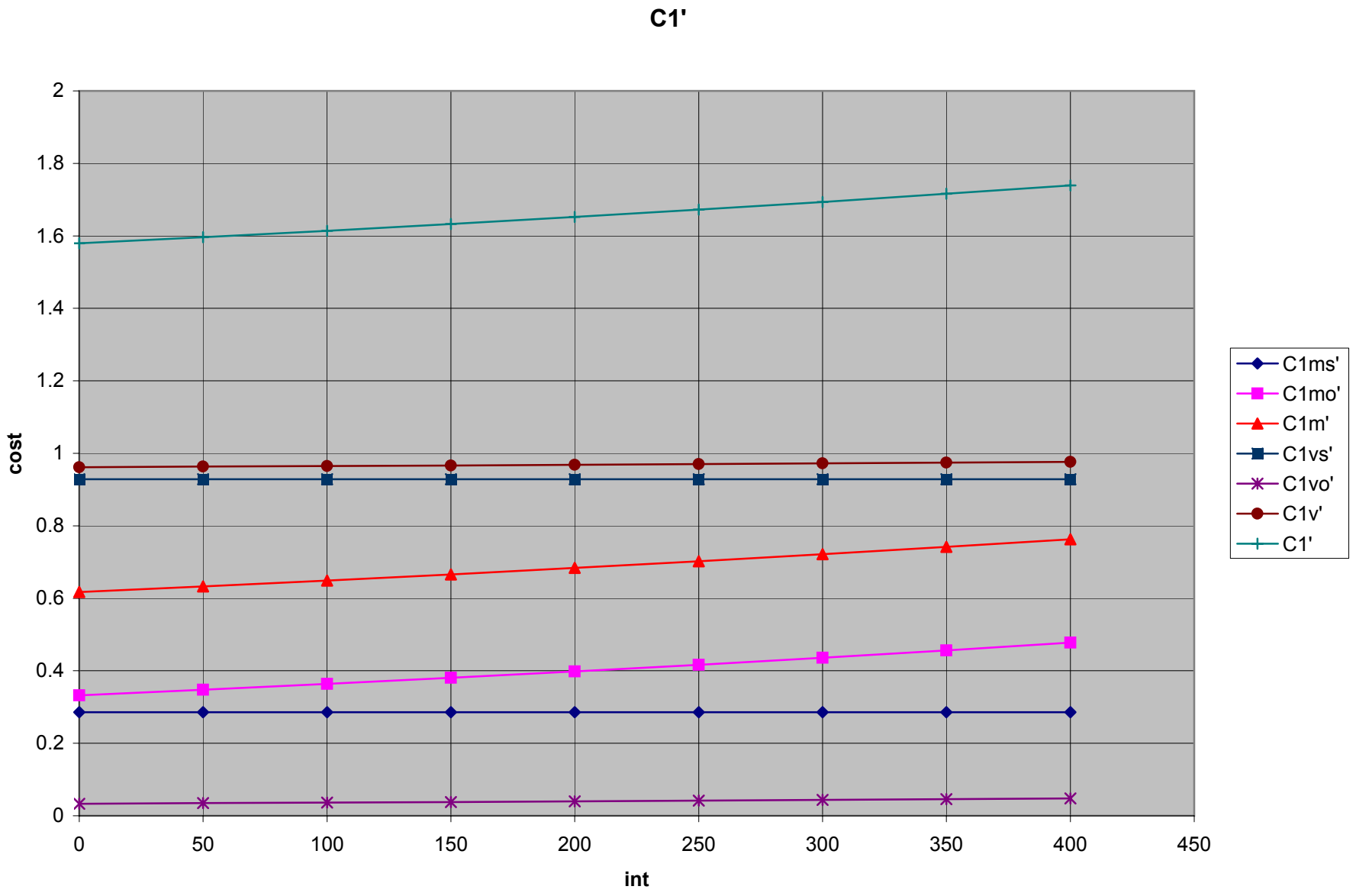
C1vs
C1vo
C1v
C1


C1'
cost
int
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0.4
0.6
0.8
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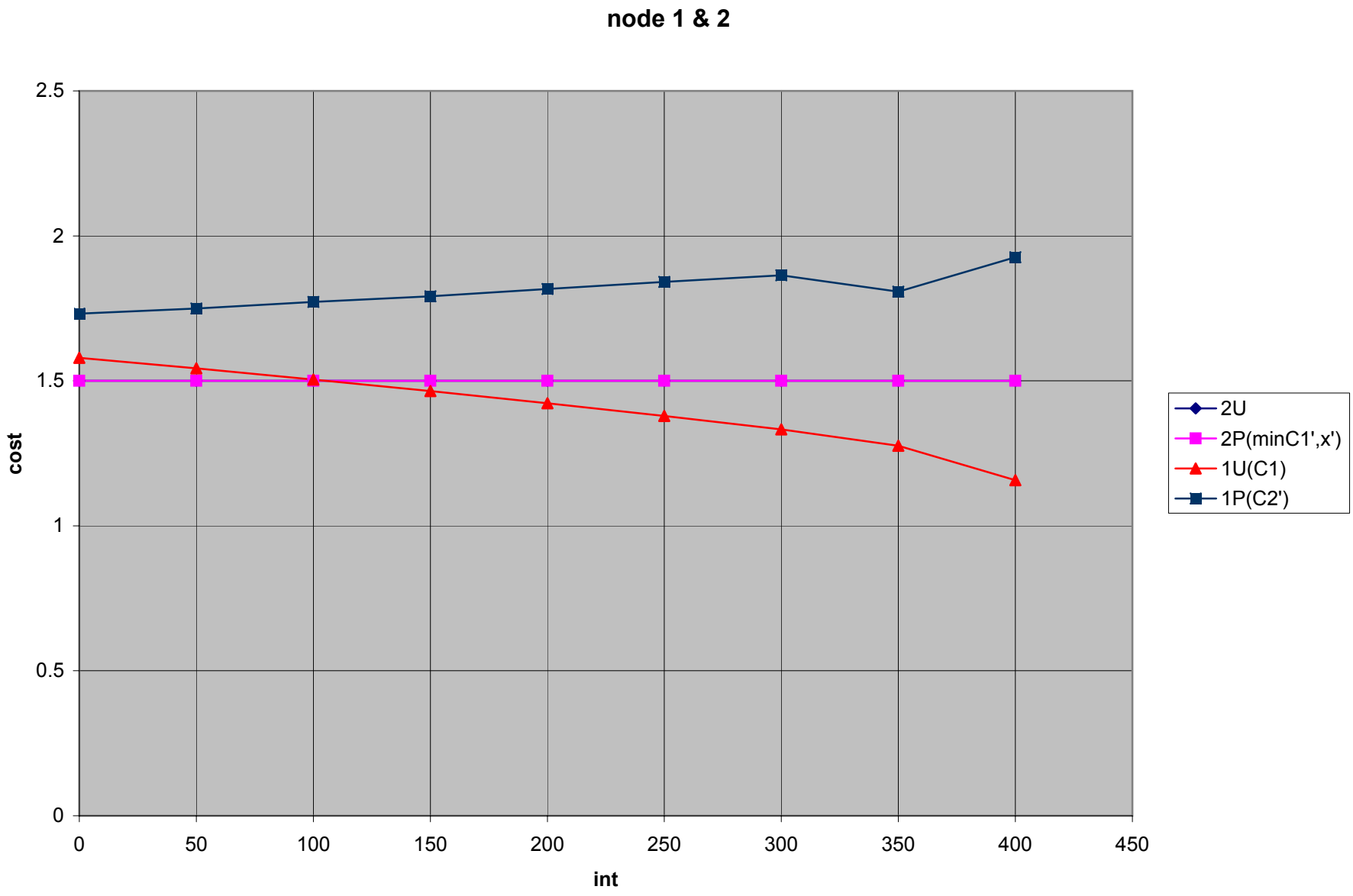
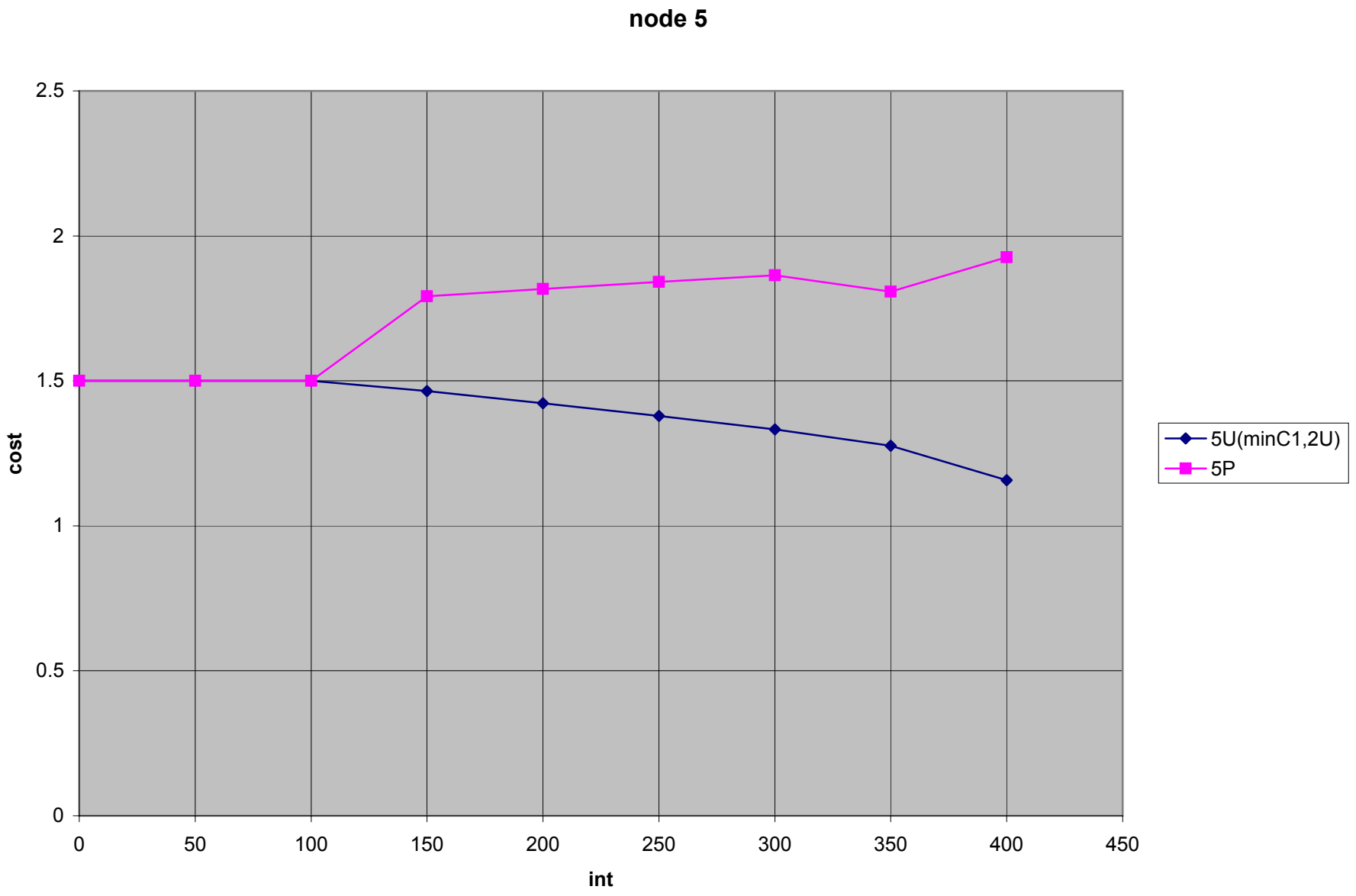
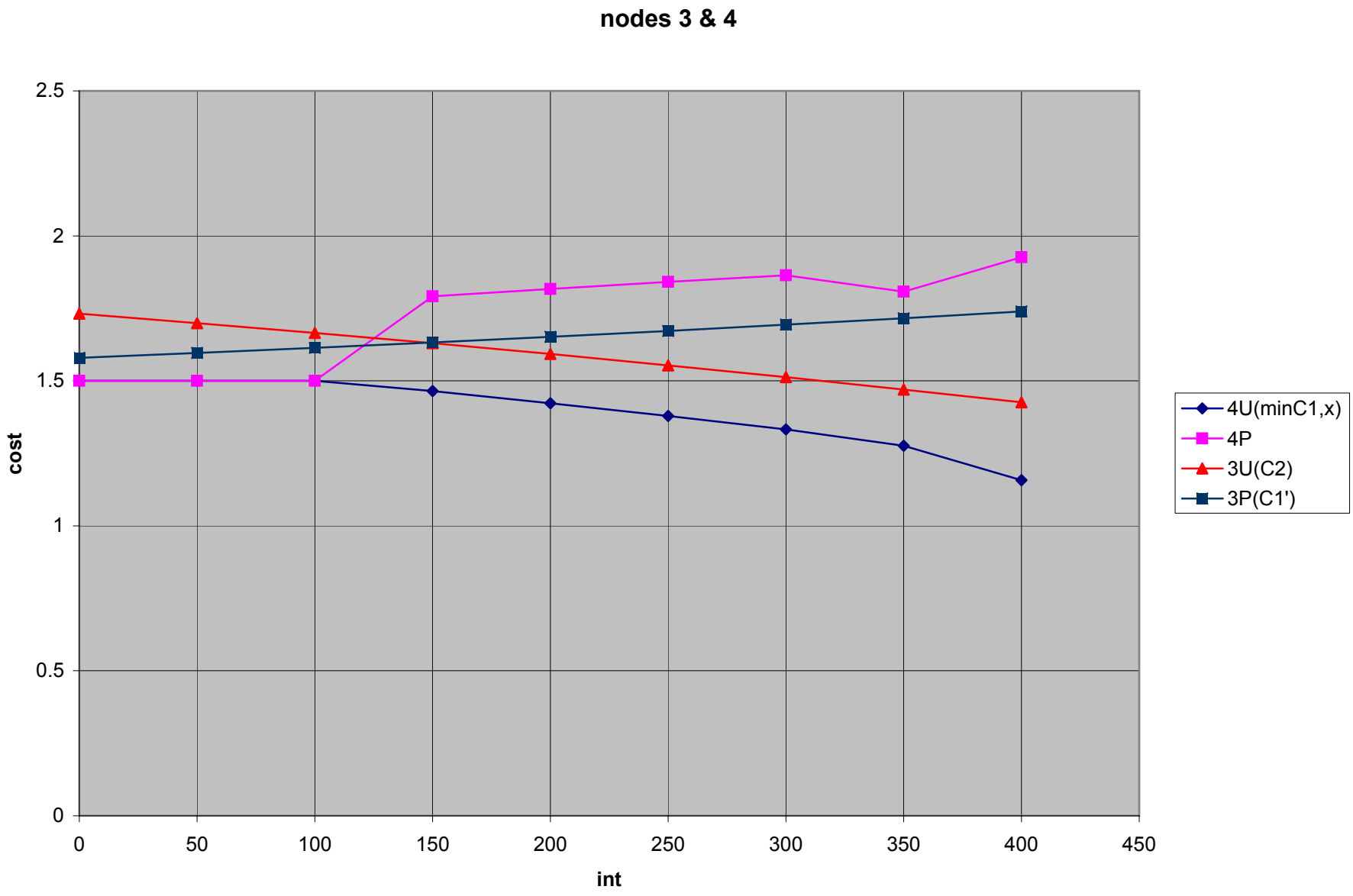
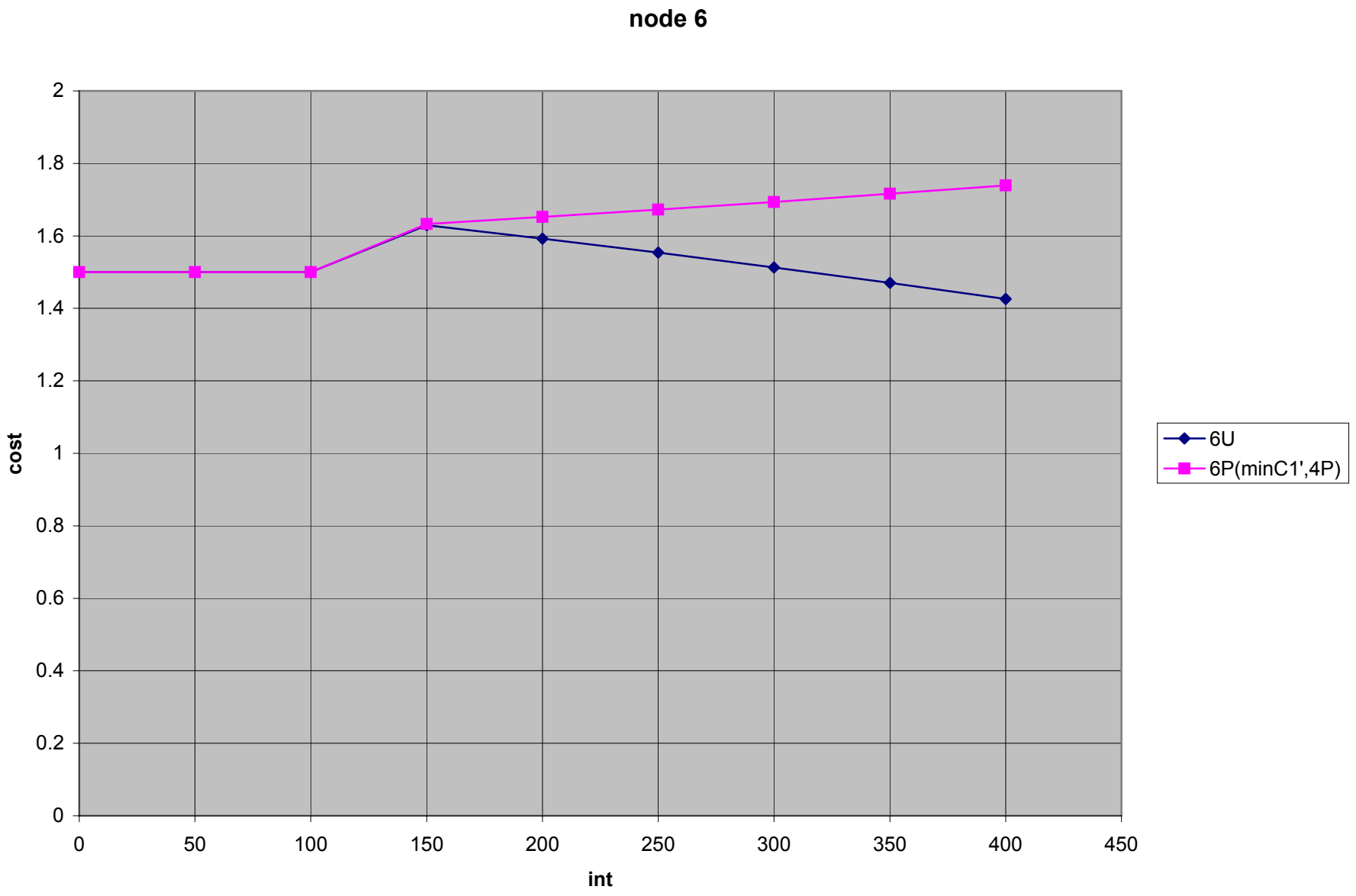
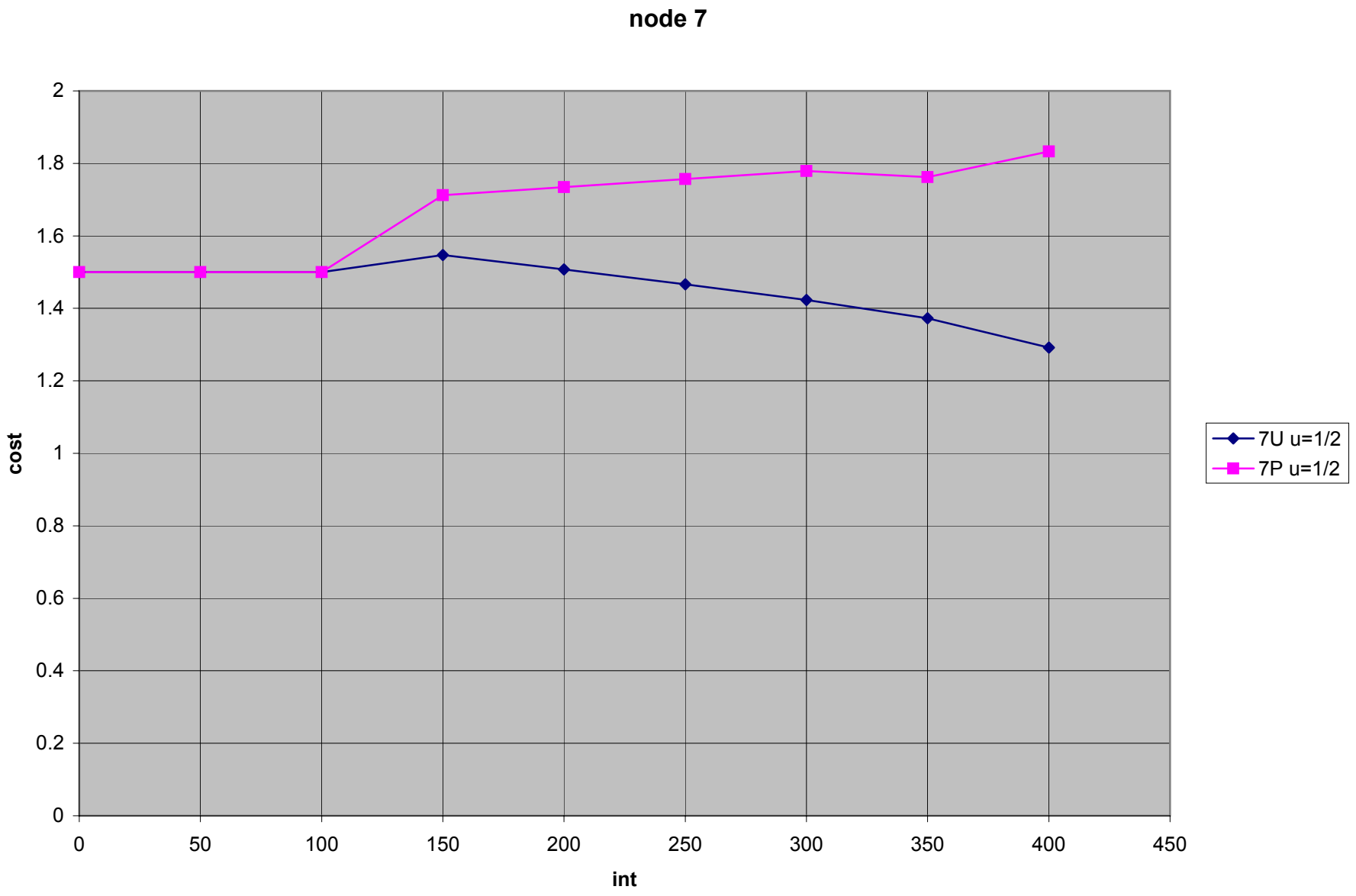
1.2
1.4
1.6
1.8
2
0
50
100
150
200
250
300
350
400
450
C1ms'
C1mo'
C1m'
C1vs'
C1vo'
C1v'
C1'


node 1 & 2
cost
int
2.5
2
1.5
1
0.5
0
0
50
100
150
200
250
300
350
400
450
2U
2P(minC1',x')
1U(C1)
1P(C2')


node 5
2.5
2
1.5
1
0.5
0
cost
0
50
100
150
200
250
300
350
400
450
int
5U(minC1,2U)
5P


nodes 3 & 4
cost
int
2.5
2
1.5
1
0.5
0
0
50
100
150
200
250
300
350
400
450
4U(minC1,x)
4P
3U(C2)
3P(C1')


node 6
cost
int
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
0
50
100
150
200
250
300
350
400
450
6U
6P(minC1',4P)


node 7
cost
int
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
0
50
100
150
200
250
300
350
400
450
7U u=1/2
7P u=1/2

p	q	m	M	n	N	W	l	p'	q'	m'	M'	n'	N'	W'	l'	f	f'	F	F'	h1	h	h'	r	int	Q'	Q'	S'	S	g1	g'	g	k	k'	v	v'	L	L'	K	V	K'	V'	Fm	Fv	Sm'	Sv'	Fm'	Fv'	Sm	Sv	C1ms	C1mo	C1m	C1vs	C1vo	C1v	C1	C1m	C1m	C1m	C1vs	C1vc	C1v'	C1'	C2ms	C2mo	C2m'	C2vs'	C2vo'	C2v'	C2'	C2	l	u	L	C1	C2	L'	C1'	C2'	7U u=	7P u=	6U	6P(mi	4U(mi	4P	3U(C	3P(C	5U(m	5P	2U	2P(mi	1U(C1	1P(C2')
1	0	2	250	2	250	1000	0	0.8	0.2	2	250	2	250	1000	0	0.2	0.2	750	750	-0	0.5	0.5	1	0	0.2	0.2	600	600	-0	0.6	0.6	0	0	0	0	0.5	0.5	1	1	1	1	409	341	336	264	409	341	336	264	0.285	0.332	0.62	0.929	0.033	0.96	1.6	0.3	0.3	0.6	0.9	0	1	1.6	0.34	0.36	0.69	0.97	0.07	1.04	1.73	1.73	0	0.5	1.5	1.6	1.7	1.5	1.58	1.7	1.5	1.5	1.5	1.5	1.5	1.5	1.73	1.58	1.5	1.5	1.5	1.5	1.58	1.73
1	0	2	250	2	250	1000	50	0.8	0.2	2	250	2	250	1000	0	0.3	0.2	746	700	-0	0.5	0.5	1	1	0.2	0.2	549	600	-0	0.5	0.6	0	0	0	0	0.5	0.5	1	1	1	1	406	340	290	259	364	336	336	264	0.251	0.333	0.58	0.925	0.033	0.96	1.5	0.3	0.3	0.6	0.9	0	1	1.6	0.33	0.37	0.71	0.97	0.07	1.04	1.75	1.7	50	0.5	1.5	1.5	1.7	1.5	1.6	1.7	1.5	1.5	1.5	1.5	1.5	1.5	1.7	1.6	1.5	1.5	1.5	1.5	1.54	1.75
1	0	2	250	2	250	1000	100	0.8	0.2	2	250	2	250	1000	0	0.3	0.2	750	650	-0	0.5	0.5	1	1	0.2	0.2	500	600	-0	0.5	0.6	0	0	0	0	0.5	0.5	1	1	1	1	409	341	245	255	319	331	336	264	0.217	0.332	0.55	0.922	0.033	0.95	1.5	0.3	0.4	0.6	0.9	0	1	1.6	0.34	0.39	0.73	0.97	0.08	1.05	1.77	1.67	100	0.5	1.5	1.5	1.7	1.5	1.61	1.8	1.5	1.5	1.5	1.5	1.5	1.5	1.67	1.61	1.5	1.5	1.5	1.5	1.5	1.77
1	0	2	250	2	250	1000	150	0.8	0.2	2	250	2	250	1000	0	0.3	0.2	744	600	-0	0.5	0.5	1	1	0.2	0.2	448	600	-0	0.4	0.6	0	0	0	0	0.5	0.5	1	1	1	1	404	340	198	250	273	327	336	264	0.18	0.334	0.51	0.918	0.033	0.95	1.5	0.3	0.4	0.7	0.9	0	1	1.6	0.33	0.41	0.74	0.97	0.08	1.05	1.79	1.63	150	0.5	1.5	1.5	1.6	1.5	1.63	1.8	1.55	1.71	1.63	1.63	1.46	1.791	1.63	1.63	1.46	1.79	1.5	1.5	1.46	1.79
1	0	2	250	2	250	1000	200	0.8	0.2	2	250	2	250	1000	0	0.2	0.3	750	550	-0	0.5	0.4	1	0	0.2	0.2	400	600	-0	0.4	0.6	0	0	0	0	0.5	0.5	1	1	1	1	409	341	154	246	228	322	336	264	0.143	0.332	0.47	0.914	0.033	0.95	1.4	0.3	0.4	0.7	0.9	0	1	1.7	0.34	0.43	0.76	0.97	0.09	1.05	1.82	1.59	200	0.5	1.5	1.4	1.6	1.5	1.65	1.8	1.51	1.73	1.59	1.65	1.42	1.817	1.59	1.65	1.42	1.82	1.5	1.5	1.42	1.82
1	0	2	250	2	250	1000	250	0.8	0.2	2	250	2	250	1000	0	0.2	0.3	750	500	-0	0.5	0.4	1	0	0.2	0.2	350	600	-0	0.3	0.6	0	0	0	0	0.5	0.5	1	1	1	1	409	341	109	241	182	318	336	264	0.103	0.332	0.44	0.91	0.033	0.94	1.4	0.3	0.4	0.7	0.9	0	1	1.7	0.34	0.45	0.78	0.97	0.09	1.06	1.84	1.55	250	0.5	1.5	1.4	1.6	1.5	1.67	1.8	1.47	1.76	1.55	1.67	1.38	1.841	1.55	1.67	1.38	1.84	1.5	1.5	1.38	1.84
1	0	2	250	2	250	1000	300	0.8	0.2	2	250	2	250	1000	0	0.3	0.2	746	450	-0	0.5	0.3	1	1	0.2	0.2	299	600	-0	0.2	0.6	0	0	0	0	0.5	0.5	1	1	1	1	406	340	62	236	137	313	336	264	0.06	0.333	0.39	0.906	0.033	0.94	1.3	0.3	0.4	0.7	0.9	0	1	1.7	0.33	0.47	0.8	0.97	0.09	1.06	1.86	1.51	300	0.5	1.5	1.3	1.5	1.5	1.69	1.9	1.42	1.78	1.51	1.69	1.33	1.864	1.51	1.69	1.33	1.86	1.5	1.5	1.33	1.86
1	0	2	250	2	250	1000	350	0.8	0.2	2	250	2	250	1000	0	0.5	0.3	500	400	-0.01	0.4	0.2	2	2	0.04	0.2	170	600	-0	0	0.6	0	0	0	0	0.5	0.5	1	1	1	1	182	318	0	170	91	309	336	264	0	0.417	0.42	0.817	0.042	0.86	1.3	0.3	0.5	0.7	0.9	0	1	1.7	0.17	0.5	0.67	0.96	0.18	1.14	1.81	1.47	350	0.5	1.5	1.3	1.5	1.5	1.72	1.8	1.37	1.76	1.47	1.72	1.28	1.808	1.47	1.72	1.28	1.81	1.5	1.5	1.28	1.81
1	0	2	250	2	250	1000	400	0.8	0.2	2	250	2	250	1000	0	0.5	0.2	500	350	-0.01	0.4	0.1	2	1	0.04	0.2	120	600	-0	0	0.6	0	0	0	0	0.5	0.5	1	1	1	1	182	318	0	120	46	304	336	264	0	0.417	0.42	0.699	0.042	0.74	1.2	0.3	0.5	0.8	0.9	0	1	1.7	0.17	0.5	0.67	0.96	0.3	1.26	1.93	1.43	400	0.5	1.5	1.2	1.4	1.5	1.74	1.9	1.29	1.83	1.43	1.74	1.16	1.926	1.43	1.74	1.16	1.93	1.5	1.5	1.16	1.93

p'	q'	m'	M'	n'	N'	W'	l'	p	q	m	M	n	N	W	l	0	F'	h1'	h'	r'	int	Q'	S	g1	g	k'	k	v'	v	L'	L	K'	V'	K	V	Fm'	Fv'	Sm	Sv	C1ms'	C1mo'	C1m'	C1vs'	C1vo'	C1v'	C1'	C2ms	C2mo	C2m	C2vs	C2vo	C2v	C2
1	0	2	250	2	250	1000	0	0.8	0.2	2	250	2	250	1000	0	0.2	750	-0	0.5	1	0	0.2	600	-0	0.6	0	0	0	0	0.5	0.5	1	1	1	1	409	341	336	264	0.285	0.332	0.62	0.929	0.033	0.96	1.6	0.34	0.36	0.69	0.97	0.07	1.04	1.73
1	0	2	250	2	250	1000	0	0.8	0.2	2	250	2	250	1000	50	0.2	700	-0	0.5	1	0	0.2	600	-0	0.6	0	0	0	0	0.5	0.5	1	1	1	1	364	336	336	264	0.285	0.347	0.63	0.929	0.035	0.96	1.6	0.31	0.36	0.66	0.97	0.07	1.04	1.7
1	0	2	250	2	250	1000	0	0.8	0.2	2	250	2	250	1000	100	0.2	650	-0	0.5	1	0	0.2	600	-0	0.6	0	0	0	0	0.5	0.5	1	1	1	1	319	331	336	264	0.285	0.364	0.65	0.929	0.036	0.96	1.6	0.27	0.36	0.63	0.96	0.07	1.04	1.67
1	0	2	250	2	250	1000	0	0.8	0.2	2	250	2	250	1000	150	0.2	600	-0	0.5	1	0	0.2	600	-0	0.6	0	0	0	0	0.5	0.5	1	1	1	1	273	327	336	264	0.285	0.38	0.67	0.929	0.038	0.97	1.6	0.24	0.36	0.6	0.96	0.07	1.03	1.63
1	0	2	250	2	250	1000	0	0.8	0.2	2	250	2	250	1000	200	0.3	550	-0.01	0.4	1	1	0.2	600	-0	0.6	0	0	0	0	0.5	0.5	1	1	1	1	228	322	336	264	0.285	0.398	0.68	0.929	0.04	0.97	1.7	0.2	0.36	0.56	0.96	0.07	1.03	1.59
1	0	2	250	2	250	1000	0	0.8	0.2	2	250	2	250	1000	250	0.3	500	-0.01	0.4	1	1	0.2	600	-0	0.6	0	0	0	0	0.5	0.5	1	1	1	1	182	318	336	264	0.285	0.417	0.7	0.929	0.042	0.97	1.7	0.17	0.36	0.52	0.96	0.07	1.03	1.55
1	0	2	250	2	250	1000	0	0.8	0.2	2	250	2	250	1000	300	0.2	450	-0.01	0.3	1	0	0.2	600	-0	0.6	0	0	0	0	0.5	0.5	1	1	1	1	137	313	336	264	0.285	0.436	0.72	0.929	0.044	0.97	1.7	0.13	0.36	0.49	0.96	0.07	1.03	1.51
1	0	2	250	2	250	1000	0	0.8	0.2	2	250	2	250	1000	350	0.3	400	-0.01	0.2	1	1	0.2	600	-0	0.6	0	0	0	0	0.5	0.5	1	1	1	1	91	309	336	264	0.285	0.456	0.74	0.929	0.046	0.97	1.7	0.09	0.36	0.44	0.95	0.07	1.03	1.47
1	0	2	250	2	250	1000	0	0.8	0.2	2	250	2	250	1000	400	0.2	350	-0.01	0.1	1	0	0.2	600	-0	0.6	0	0	0	0	0.5	0.5	1	1	1	1	46	304	336	264	0.285	0.478	0.76	0.929	0.048	0.98	1.7	0.04	0.36	0.4	0.95	0.07	1.02	1.43

u	L/L+1	C1	C2	L'/L'+	C1'	C2'	7U15	7P15	6U	6P(m	4U(m	4P	3U(C	3P(C	5U(m	5P	2U	2P(m	1U(C	1P(C2')
0.5	0.5	0.1	0.5	0.5	0.5	0.5	0.1	0.5	0.1	0.5	0.1	0.5	0.5	0.5	0.1	0.5	0.5	0.5	0.1	0.5
0.5	0.5	0.2	0.5	0.5	0.5	0.5	0.2	0.5	0.2	0.5	0.2	0.5	0.5	0.5	0.2	0.5	0.5	0.5	0.2	0.5
0.5	0.5	0.3	0.5	0.5	0.5	0.5	0.3	0.5	0.3	0.5	0.3	0.5	0.5	0.5	0.3	0.5	0.5	0.5	0.3	0.5
0.5	0.5	0.4	0.5	0.5	0.5	0.5	0.4	0.5	0.4	0.5	0.4	0.5	0.5	0.5	0.4	0.5	0.5	0.5	0.4	0.5
0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
0.5	0.5	0.6	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.6	0.5
0.5	0.5	0.7	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.7	0.5
0.5	0.5	0.8	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.8	0.5
0.5	0.5	0.9	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.9	0.5