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Properties of the USPTO patent citation network: 1963–2002 ☆

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ABSTRACT

The network of patent citations is a collection of clumps of citations between closely related patents, with the largest clumps being defined by patent technology categories. The exchange of citations between these groups evolves over time and reveals technological trends. By using USPTO data and considering the evolution of backwards- and forwards-, and intra- and inter-citations, conclusions about the generality, originality, and productivity of patents and technology categories can be drawn.

1. Introduction

Much has been done to discover economic meaning in the quantities of patents or patent citations between firms or countries with, for example and *inter alia,* [1–8]. More recently efforts have been made to find economic meaning within medium- and micro-structures of the network of patent citations, considering for example network properties adapted from social network and bibliometric analysis [9], network topological properties over time [10–12]. Analysis is often done on particular structures – clumps, clusters, or thickets of citations – that occur at various scales of technology categories or by company or country. See for example [13–15].

Patent citations are part of the legal patent process wherein the patent applicant has the duty to disclose any knowledge of 'prior art' amongst previous patents. Some objectivity in the process is provided by the government patent examiner who is an expert in the area and who approves the final citation. Nevertheless, in the end the process is not necessarily a reliable one as applicants usually have strategic motives to avoid making certain citations or to falsely claim others. Similarly, the examiner and the examination agency may not have any motivation – beyond professional integrity – to maintain any consistency in their approval of citations.

This article uses two of the five patent citation databases collected by Hall, Jaffe, and Trajtenberg (HJT) [16], and published on the National Bureau of Economic Research (NBER), the NBER website (http://www.nber.org/patents/). The first is the primary database (*cite75_02.zip*) that contains a pair-wise patent citation dataset of more than four million US patents granted between January 1963 and December 2002, and the second is next largest database (*pat63_02f.zip*) that contains the application and granting dates for each patent, the owner and geographic location of the patent assignee, the technological category of the patent, and statistics of generality and originality based on the composition of the citations.

The citation-pairs database defines a patent citation network. Naturally, patent citations, like other citations, only travel back in time so that the resulting network never contains any loops. Gress [17] details how to assemble, visualize, and analyze these networks with *Mathematica*. Fig. 1 is an illustration of the patent citation network in the neighborhood of a few select patents. The diagram illustrates a 'flow of ideas over time' with time extending down the page and with citations represented as arrows going down the page between patents.

Of course citations are always to patents earlier in time (up the page), but drawing them in this fashion is more suggestive of one patent giving birth to the next. Thus 'forward citations' coming into a patent are illustrated here as arrows coming out of the bottom of the patent node, while 'backwards citations' to previous patents are shown as arrows coming into the top of a patent.

And of course Fig. 1 is only a tiny patch of the entire network of 4,323,518 patent nodes and 22,309,440 citation edges recorded as of 2002. Fig. 2 illustrates a larger patch of the network, the patent neighborhood of patent US3858382 out to a network distance of 4-shaded (colored) by the patent technology category. This graph is not lain out over time, and instead is drawn with an algorithm that minimizes distances between connected nodes while simultaneously applying a repulsive force to all nodes.

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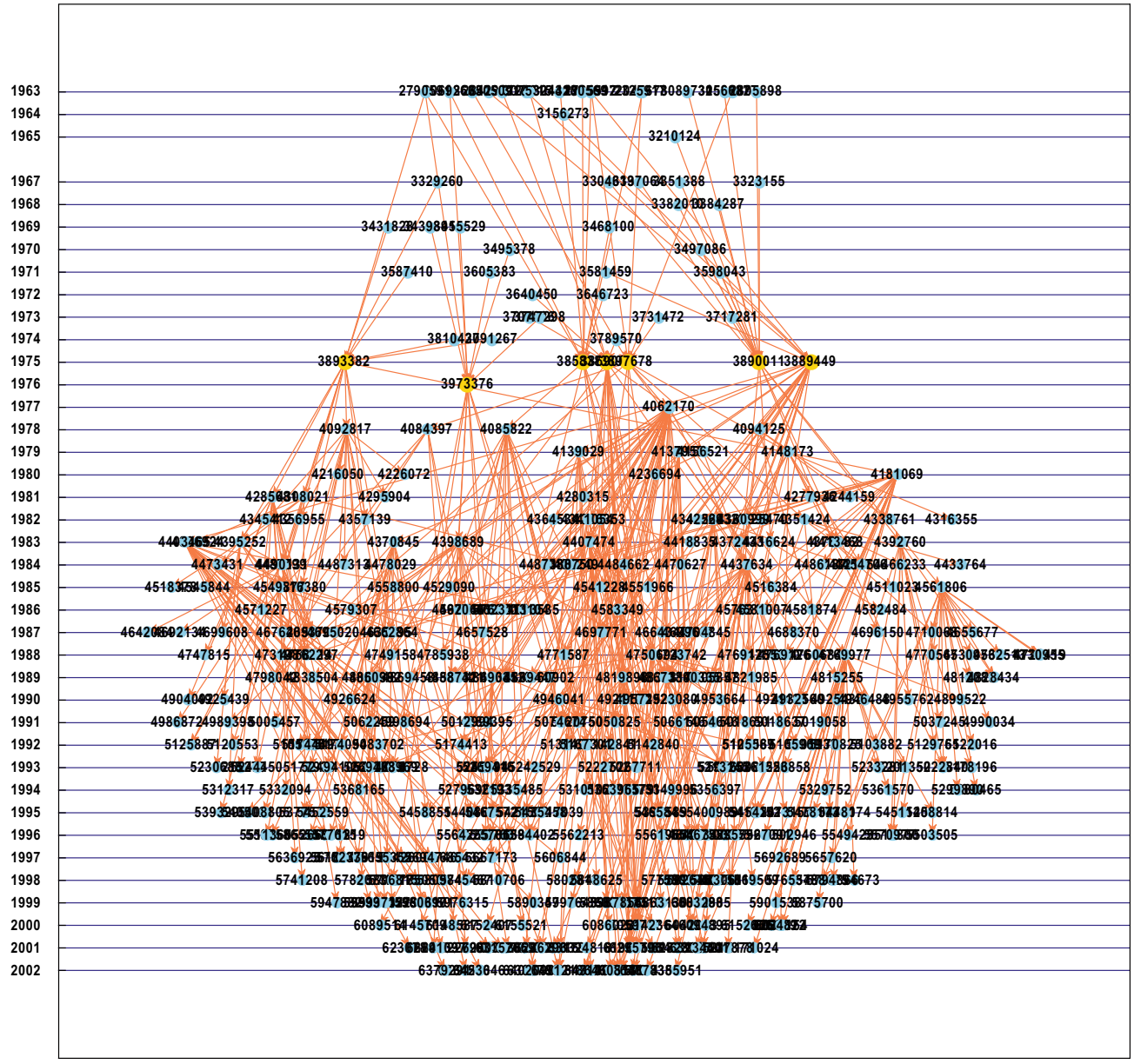

Fig. 1. The distance-2 citation neighborhood around six patents from 1975.

Looking at Figs. 1 and 2 reveals a number of characteristics of the network. First, citations and patents seem to explode over time. As we move through time (down the page in Fig. 1 or from the center out in Fig. 2) we encounter an increasing number of new patents at every step. Second, there is a clumpy texture to the network – also known as 'thickets' in the literature. Some areas have intense citation activity while others have very sparse activity. Finally, the shading (coloring) of Fig. 2's patents and citations by technology category shows that while different categories definitely exchange citations across categories, there are enough intra-category citations to clearly group the categories into clumps.

Unfortunately, even visualizing relatively small patches of the network is very computationally expensive. Fig. 2 contains only 18,316 nodes – barely four-thousands of the entire network – yet it takes 30 min to calculate and render. So, until computational power catches up, we can only hope for some statistical synopsis of the larger structure.

2. Intra- and inter-, backwards- and forwards-citations

2.1. An overview

Fig. 3 illustrates the structure of the data considered in much of subsequent analysis. Consider two sets of patents grouped into two technology categories, A and B, and also grouped by year. Each of these smaller annual groups – for example within A for the year 2000 – will have some number of citations from or to other patents in that same year, the a arrow in the diagram. There will also be some citations to earlier A patents (b), citations from later A patents (c), citations to previous year's patents within the B technology category ('d'), citations from patents from the same year in B (e), and citations from later patents in B (f).

Citations a, b, and c – all within tech category A – are 'intra-citations'. Citations d, e, and f – either to or from B patents – are 'inter-citations'. Citations b and d, (and depending on the definition, also a and e) are 'backwards-citations', while citations c and f are 'for-

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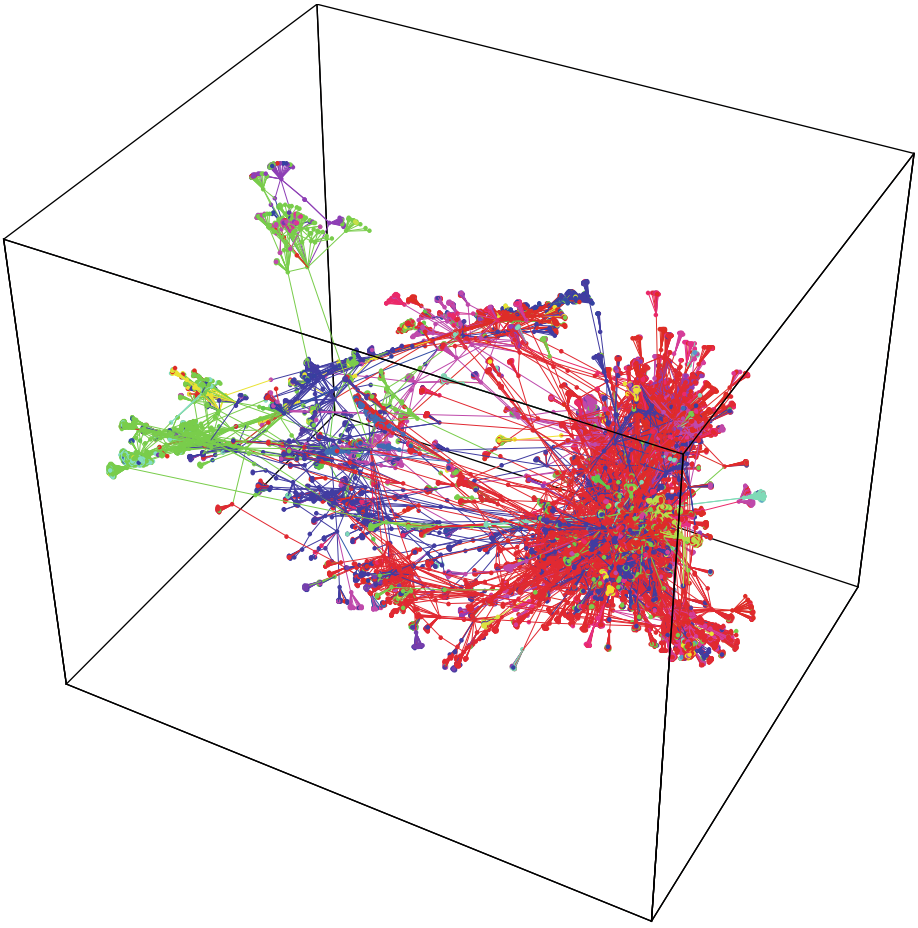

Fig. 2. The distance-3 citation neighborhood around patent #3858382, colored by technology category.

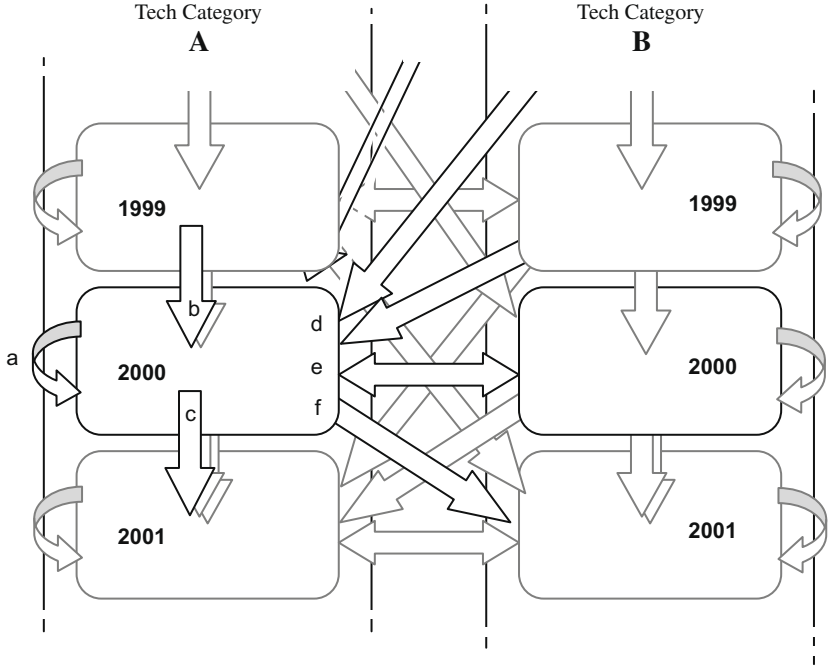

Fig. 3. Forwards- versus backwards-, and inter- versus intra-citations between two technology categories.

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Table 1
HJT 2-digit technology category definitions, distributions, and statistics, 1975–2002.

HJT category	HJT sub category	Category name	Sub category name	Patent count	Frequency	Backwards-citation count	Backwards-citations per-patent	Intra- and backwards-citations	Intra-citation rate	Forwards-to-backwards citation ratio	Expected up-out-citations	?	Self-citations per patent
1	11	Chemical	Agriculture, Food, Textiles	19,745	0.779	128,660	6.516	50,124	0.390	0.965	7692.355	19049.92	2.538567
1	12		Coatings	39,329	1.513	298,245	7.583	115,387	0.387	1.075	15215.86	42292.83	2.933891
1	13		Gas	11,750	0.483	114,205	9.720	68,373	0.599	0.751	7034.567	8820.373	5.818979
1	14		Organic Compounds	83,391	3.532	425,058	5.097	202,430	0.476	0.744	39714.2	62040.9	2.42748
1	15		Resins	86,023	3.300	664,918	7.730	392,273	0.590	1.191	50749.87	102481.8	4.560094
1	19		Misc Chemical	249,661	9.818	1980,941	7.935	1279,782	0.646	0.966	161292.9	241244.9	5.126079
2	21	Computers and	Communications	133,528	4.724	1133,120	8.486	786,284	0.694	1.414	92656.5	188803.3	5.888533
2	22	Communications	Computer Hardware and Software	110,306	3.600	1063,200	9.639	675,783	0.636	1.607	70111.85	177243	6.126439
2	23		Computer Peripherals	39,137	1.243	285,549	7.296	176,366	0.618	1.411	24172.51	55224.66	4.506375
2	24		Information Storage	62,275	2.088	459,044	7.371	313,955	0.684	1.587	42591.88	98825.44	5.041429
2	25	Unknown*	Unknown	2534	0.078	43,362	17.112	1028	0.024	0.139	60.07454	353.4727	0.405683
3	31	Drugs and Medical	Drugs	102,505	3.304	499,255	4.871	369,522	0.740	1.163	75868.75	119164.1	3.604917
3	32		Surgery & Med Inst.	79,713	2.699	1043,544	13.091	850,795	0.815	1.702	64989.52	135666.7	10.67323
3	33		Biotechnology	28,369	0.930	185,454	6.537	73,484	0.396	1.616	11240.89	45837.21	2.590292
3	39		Misc Drugs & Med	18,383	0.629	175,775	9.562	118,522	0.674	1.639	12395.33	30123.49	6.44737
4	41	Electrical and	Electrical Devices	83,382	3.374	580,580	6.963	354,424	0.610	0.959	50901.83	79945.99	4.250606
4	42	Electronic	Electrical Lighting	41,944	1.606	273,054	6.510	183,386	0.672	1.086	28170.04	45544.05	4.372163
4	43		Measuring & Testing	74,165	2.849	517,452	6.977	301,263	0.582	1.093	43179.21	81070.5	4.062064
4	44		Nuclear & X-rays	37,988	1.432	257,269	6.772	138,446	0.538	1.174	20442.75	44603.99	3.644467
4	45		Power Systems	92,864	3.602	702,956	7.570	437,679	0.623	1.020	57819.58	94762.14	4.713118
4	46		Semiconductor Devices	74,610	2.434	562,282	7.536	424,771	0.755	1.528	56363.47	114013	5.693218
4	49		Misc Elec	64,899	2.414	499,934	7.703	259,680	0.519	1.200	33710.39	77910.6	4.001294
5	51	Mechanical	Mat. Proc & Handling	125,369	5.362	906,267	7.229	550,686	0.608	0.709	76179.48	88871.58	4.392521
5	52		Metal Working	73,177	3.016	439,630	6.008	243,114	0.553	0.735	40466.65	53811.95	3.322273
5	53		Motors, Engines & Parts	93,676	3.693	618,720	6.605	440,961	0.713	0.736	66762.77	68987.97	4.7073
5	54		Optics	60,370	2.196	421,386	6.980	270,795	0.643	1.201	38795.53	72530.93	4.485589
5	55		Transportation	74,914	3.019	494,231	6.597	349,215	0.707	0.754	52932.93	56517.82	4.661545
5	59		Misc Mechanical	121,299	5.049	860,622	7.095	510,698	0.593	0.727	71979.52	88197.47	4.210241
6	61	Others	Agriculture, Husbandry, Food	51,857	2.102	363,040	7.001	274,402	0.756	0.736	39195.86	38185.89	5.291513
6	62		Amusement Devices	26,925	1.032	189,994	7.056	150,048	0.790	0.853	21264.05	22955.5	5.572813
6	63		Apparel & Textile	40,512	1.725	260,451	6.429	187,088	0.718	0.569	29100.71	23034.07	4.618088
6	64		Earth Working & Wells	34,114	1.434	270,882	7.940	211,315	0.780	0.612	26612.33	20873.81	6.194378
6	65		Furniture, House Fixtures	51,756	2.071	356,550	6.889	246,877	0.692	0.651	35836.11	33687.2	4.770017
6	66		Heating	31,598	1.281	207,169	6.556	129,506	0.625	0.738	19752.62	23314.46	4.098551
6	67		Pipes & Joints	21,734	0.909	170,809	7.859	91,070	0.533	0.666	11587.89	14464.32	4.190209
6	68		Receptacles	49,649	2.069	445,852	8.980	289,148	0.649	0.760	32198.82	37740.74	5.823843
6	69		Misc Others	214,998	8.613	1535,164	7.140	888,870	0.579	0.775	124485.2	166603.9	4.134318
Total or average				**2608,449**	**100**	**19,434,624**	**7.451**	**12,407,550**	**0.634**	**1.025**			
Totals and averages by 1-digit tech category													
				Total	**Total**	**Total**	**Average**	**Total**	**Average**	**Average**			
1		Chemical		489,899	19.43	3612,027	7.373	2108,369	0.584	0.802			4.303681
2		Computers and Communications		345,246	11.66	2940,913	8.518	1952,388	0.664	0.881			5.655063
3		Drugs and Medical		228,970	7.56	1904,028	8.316	1412,323	0.742	0.840			6.168157
4		Electrical and Electronic		469,852	17.71	3393,527	7.223	2099,649	0.619	0.853			4.468745
5		Mechanical		548,805	22.34	3740,856	6.816	2365,469	0.632	0.761			4.310218
6		Others		523,143	21.24	3799,911	7.264	2468,324	0.650	0.731			4.718,259

* Category 25 (Unknown) is probably a data error.

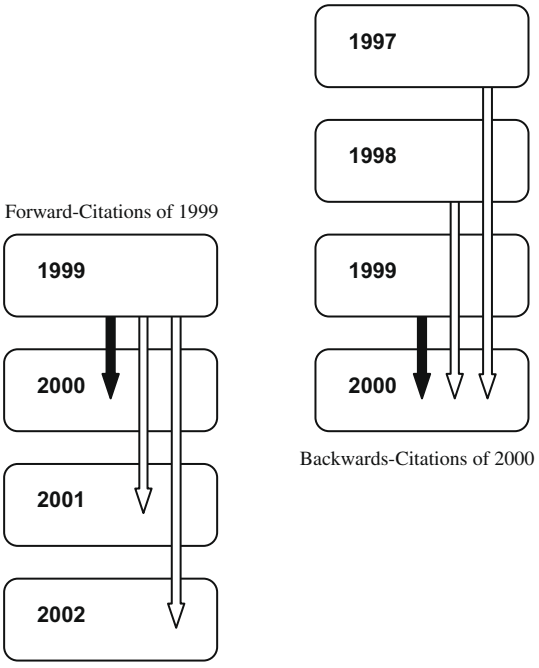

Fig. 4. The forward-citations of one year do not equal the backwards-citations of the next.

wards-citations'. A patent's backwards-citations are determined once, at the time of issuance, but a patent's forwards-citations are constantly being added to over time. Table 1 breaks out these statistics for the entire USPTO dataset.

While it would seem that since one year's forwards-citations are just the next year's backwards-citations – so that backwards- and forwards-citation sets should be identical – in fact this forgets that (for example) the backwards-citations from the year 2000 not only includes citations to patents in 1999, but also to 1998, as well as every other earlier year in the set. And in the same fashion, the forwards-citations for the year 2000 include the patents in 2001 and 2002, the last date in the dataset. Because of this the forwards-citations of 1999 do not equal the backwards-citations of 2000. Fig. 4 illustrates this case, where the only common citations between the two sets (highlighted) are those from 1999 to 2000. Fig. 3 only illustrates the backwards-citation sets.

Another difference between backwards- and forwards-citation sets is that forwards-citation sets are subject to 'truncation'. Assuming that we have the entire patent citation dataset going back to the first-ever patent, then the backwards-citations sets will always be complete as soon as a patent is filed. However the forwards-citation sets will always be subject to revision as future patents create new backwards-citations. Fig. 5 makes this clearer. Starting in 1975 when records of backwards-citations become available, the number of backwards-citations increases pretty regularly, generally matching the growth of new patents. However the numbers of forwards-citations made each year, (whose records in fact go back much earlier), start to turn down, actually equaling the backwards-citations around 1993, and then approaching zero as we get closer to the last record in 2002. This is due to the 'truncation' of the 'true' dataset.

It is impossible to know what the true trend for backwards-citations will be as the citation dataset will never be closed and even citations to the oldest patents in existence are theoretically possible. If we were to base a model for backwards-citations on the period of time from 1963 to 1990, then we could imagine that in the future new patents and citations will be created in some fashion such that forwards-citations maintain a constant distance above the backwards-citations. In the end, any statements about

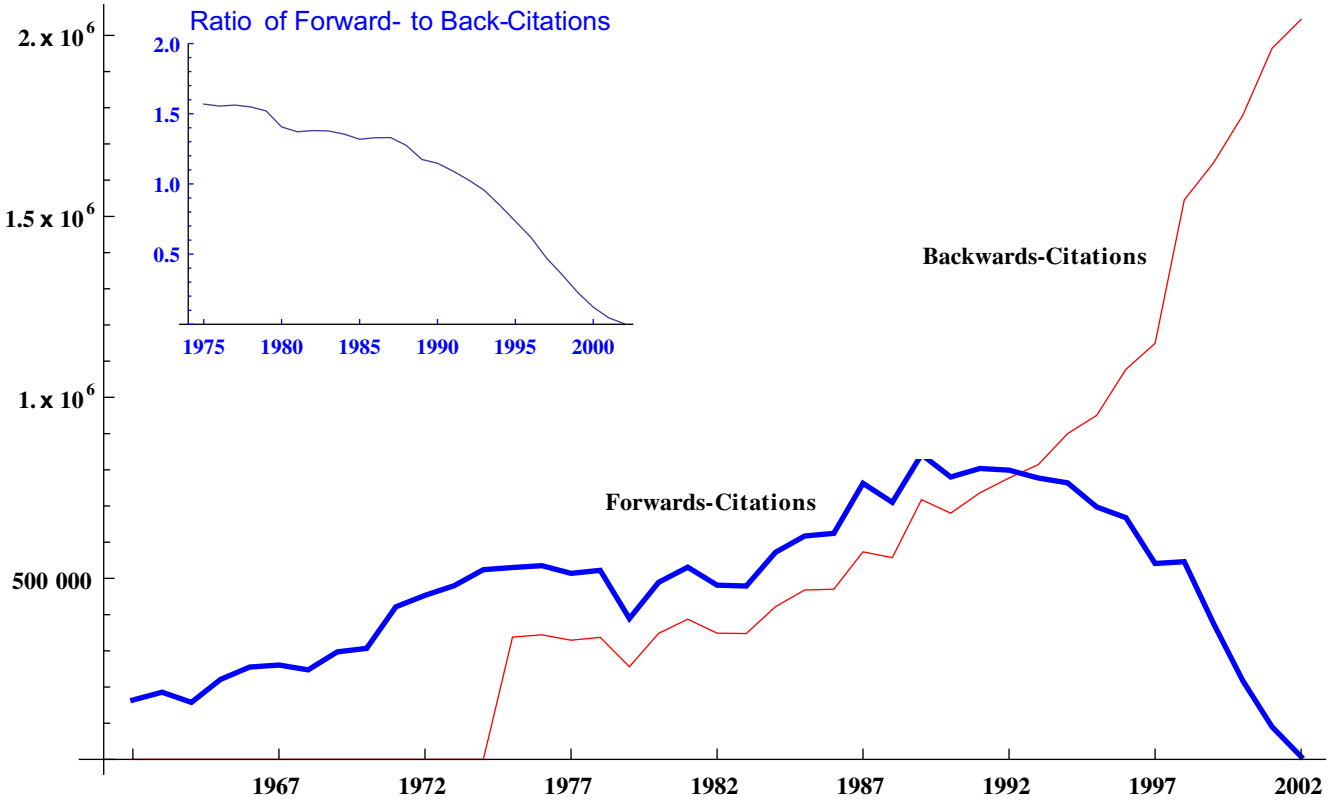

Fig. 5. Number of forward- and back-citations, 1962–2002.

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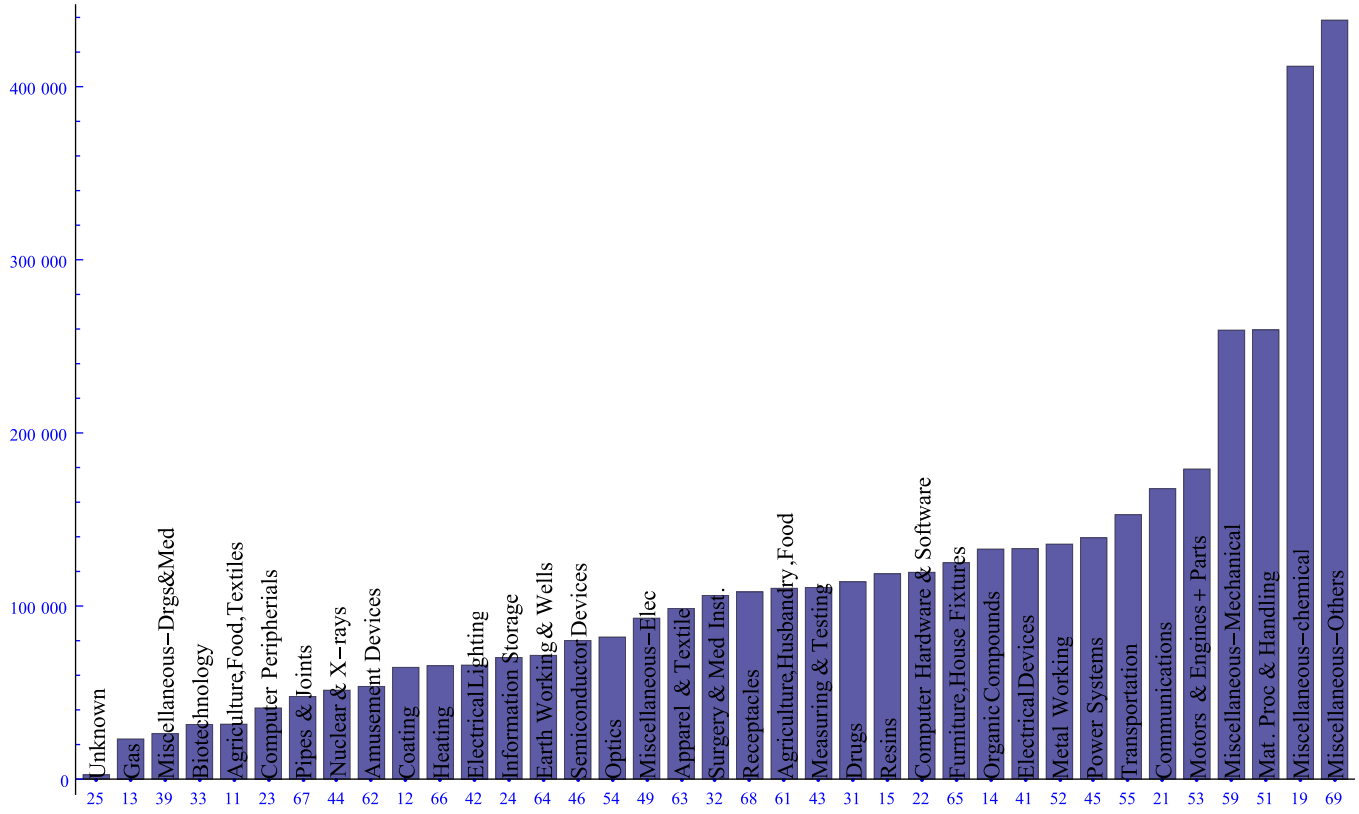


Fig. 6. Distribution of numbers of patents in HJT technology categories, 1963–2002.

backwards-citations must assume a model of how both patents and their citations will be generated in the future[1].

Each type of citation – intra-, inter-, backwards-, or forwards- – can have a different economic interpretation. HJT [16] uses the number and diversity of backwards-citations as a measure of a patent's generality, assuming that the more (and more diverse) patents one cites, the more generally applicable is the new technology. One could also imagine this to be a measure of a patent's lack of innovation, the degree of its 'derivativeness' from previous technology. They also use the number (and diversity) of forwards-citations as a measure of a patent's productivity and originality. Unfortunately, because these statistics are based on Hirfindahl-type indexes that do not weight citation counts – only shares – so their interpretation is often unclear.

The intra- and inter-citations between groups of patents can be a measure of the groups' interdependence and relative contributions. Intra-citations are an indicator of a technology's independence from other groups.

3. Macro structures – technology categories

HJT [16] introduces a technology classification system that condenses the approximately 400 USPTO categories into a 2-digit, 36-category system. The first digit of each category also defines a 1-digit, 6-category system divided into *Chemical, Drugs and Medical, Electrical and Electronic, Mechanical, Computers and Communications, and Others*. Fig. 6 shows the distributions of the total numbers of patents over time and amongst the 36 categories.

At the 6-category level, Mechanical (category 5) and Others (category 6) are the two largest groups, with around half-a-million patents each over the period from 1975 to 2002. Each is nearly twice as large as the smallest group, Drugs and Medical (3), with about 228 thousand patents. However, citations-wise, five of the six groups make about the same number of citations, around 3 to 3-and-a-half million total citations each. Drugs and Medical, however has a little less than two million. This results in citations-per-patent rates that don't vary as much, from almost 7 citations-per-patent for Mechanical to a little more than 8-and-a-half for Computers and Communications.

Since any technology categorizing system is arbitrary and not natural, it is reasonable to wonder to what degree the patents in each category reasonably reside there. It is possible that two separate categories listed on paper are otherwise indistinguishable based on the actual behaviour of their citations. They might actually cite one another so much that they are more accurately described as a single category, or in the same fashion, some category might actually be comprised of a number of subgroups that hardly ever cite one another.

3.1. Inter-category citation trade

A first indicator of the interdependence of technology categories is the degree to which they trade citations. Two categories that cite one another highly and regularly are clearly more dependent and similar than those that don't. Fig. 7[2] shows the trade between the 36 technology categories, in total backwards-citations, for the whole 28 year period from 1963 to 2002. Clearly identifiable are the two main technology super-structures: chemicals on the left side, and computers and mechanical devices on the right. *Drugs, Miscellaneous-Chemical, Organic Compounds, and Biotechnology* form the core of the first group, while Computer Hardware and

[1] Marco [19] is one such attempt to model citation creation.

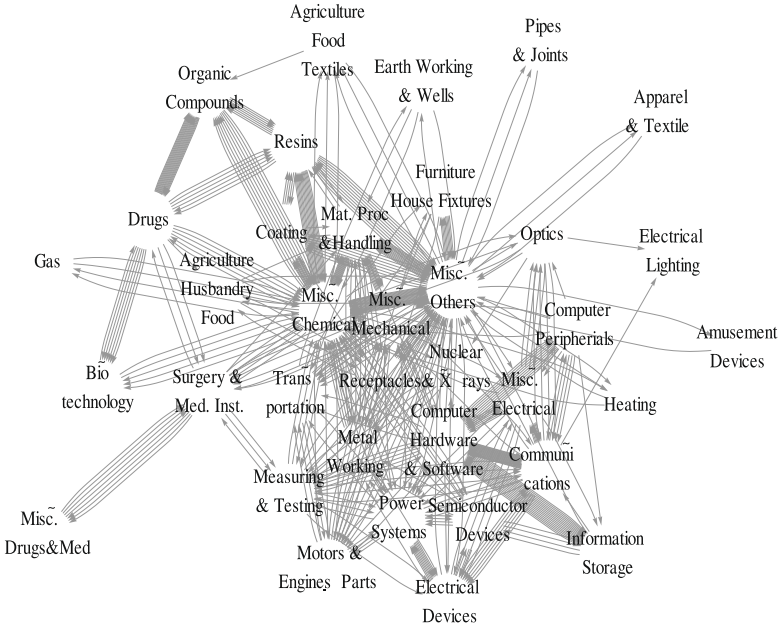
[2] Ref. [18] contains interactive versions of Figs. 7–9 online.

Software, Communications, Electrical Devices, and Computer Peripherals form the core of the second. Categories like *Miscellaneous-Chemical*, *Miscellaneous-Others*, Optics, Measuring and Testing, and Semiconductor Devices act as intermediary categories between these two primary groups, seemingly converting the ideas of the one to ideas for the other. Some categories lead ancillary roles, either as citation parasites on the main categories (e.g. Electrical Lighting, or Pipes and Joints), or as citation vassals (e.g. Amusement Devices).

The net flow of citations in Fig. 8 provides a clearer vision of the surplus and deficits in the flows of citations. Now it can be seen that some categories like Drugs, Semiconductors, and Computer Peripherals are the source of much of the innovation in the US, whereas categories like Organic Compounds and Biotechnology are sinks. When only net citations above some threshold are considered, then it becomes more obvious that some categories exchange citations with the central throng so rarely that they are almost entirely independent.

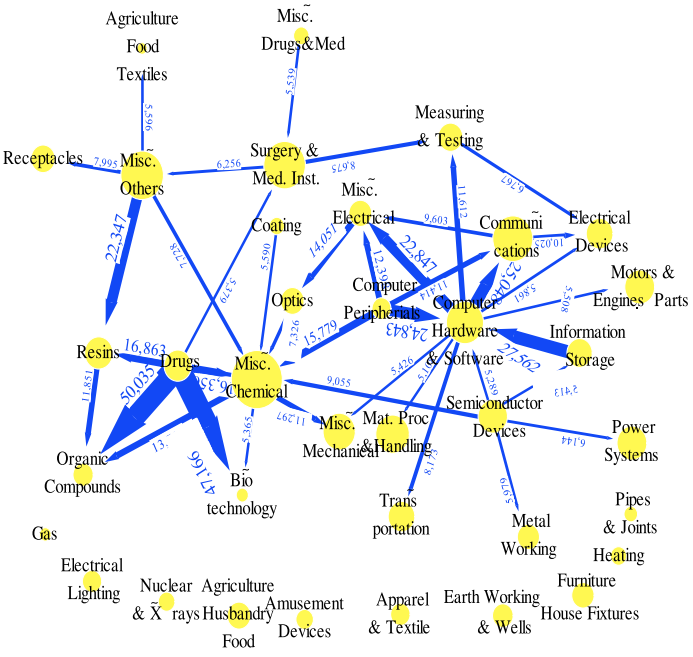
Total Up Citations between Technology Categories

All lines with fewer than 9000 citations deleted. Each line 9000 citations. 1975 to 2002



Net Citations between Technology Categories

All lines with fewer than 5000 citations deleted. 1965 to 2002



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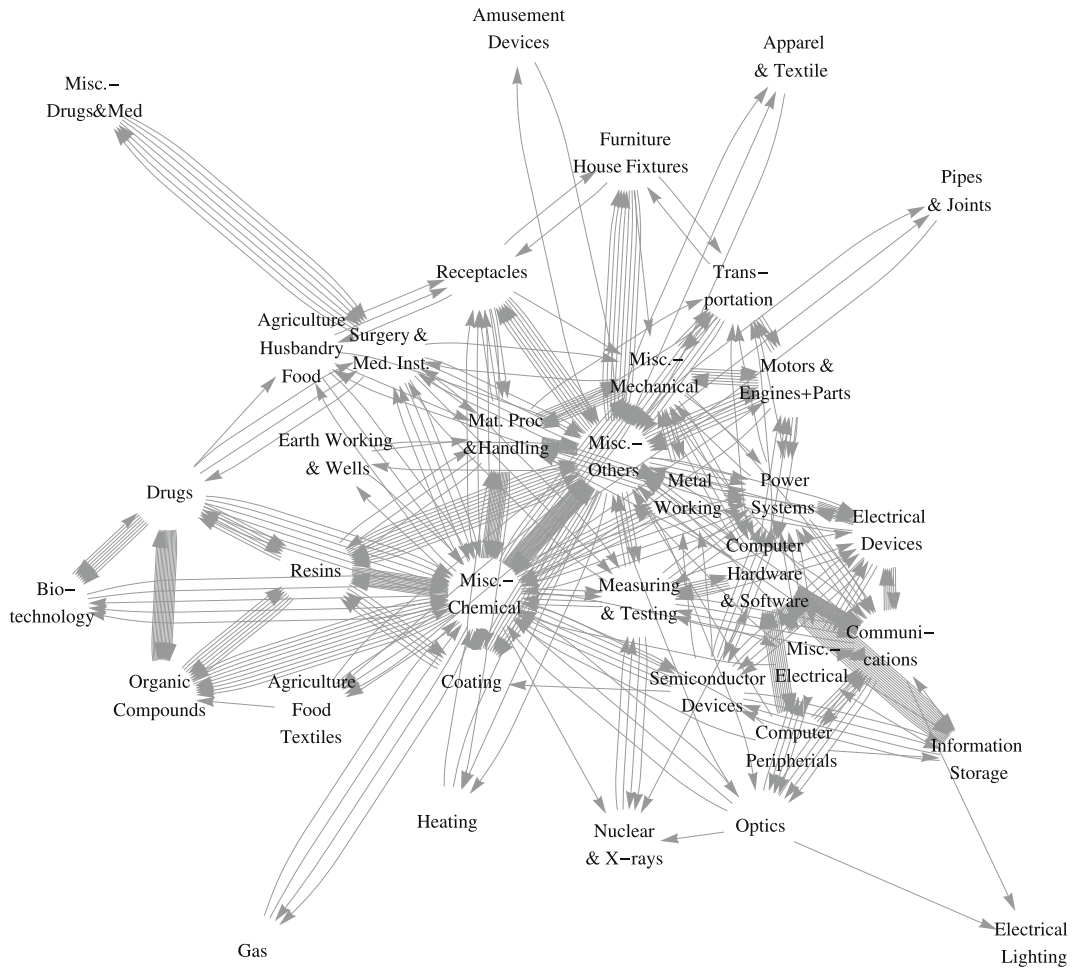

Fig. 7. Total backwards-citations between technology categories.

Fig. 9 zooms out even further to the 1-digit technology category level. Here we can see that for these wider categories, opposite conclusions can be had. Now *Computers and Communications* and *Drugs and Medical* are sinks while *Chemical and Electrical and Electronics* are sources for citations, and *Mechanical* and *Others* are intermediary categories. These seemingly contradictory results merely illustrate that on different scales of aggregation different things are going on. Just as Colorado has a trade deficit with California, but both have trade deficits with China. The wider categories define different universes of activity.

These three Figs. 7–9) fail however to consider two factors that may temper these conclusions. The first is that if all patents cite one another with equal probability, then technology categories with more patents should receive larger portions of the total inter-citations from the other categories. Second, different technology categories have different per-patent citation rates. This may be because of different traditions in the various fields, or because of actual differences in innovativeness. The next section accounts for these issues.

4. Disequilibrium citation rates

Tables 2 and 3 show the differences between the actual citation rates of each category versus their 'expected' backwards- (or forwards-) citation rates. The expected citation rate is the percentage of citations that would go to another group of patents assuming that all patents have an equal probability of citing one another. I call this the disequilibrium citation rate, pretending for the moment that in some sort of equilibrium, all patents would cite each other with equal probabilities:[3]

$$\text{Equilibrium Citation Deficit} = \frac{C_{i,k}}{C_i} - \frac{C^e_{i,k}}{C_i} = \frac{C_{i,k}}{C_i} - \frac{C_i^{\frac{N_k}{N}}}{C_i} = \frac{C_{i,k}}{C_i} - \frac{N_k}{N}$$

which is just difference between the percentage of (either backwards- or forwards-) citations going from the ith category to the kth, of the total number citations from the ith category (C_i):

$$\text{Citation Rate from ith Category to kth} \equiv \frac{C_{i,k}}{C_i}$$

and the expected number of citations from the ith category to the kth:

$$C^e_{i,k} = C_i \frac{N_k}{N}$$

where

$$C_i = \sum_k C_{i,k}$$

[3] Maybe I should call this the 'Entropy Citation Surplus'.

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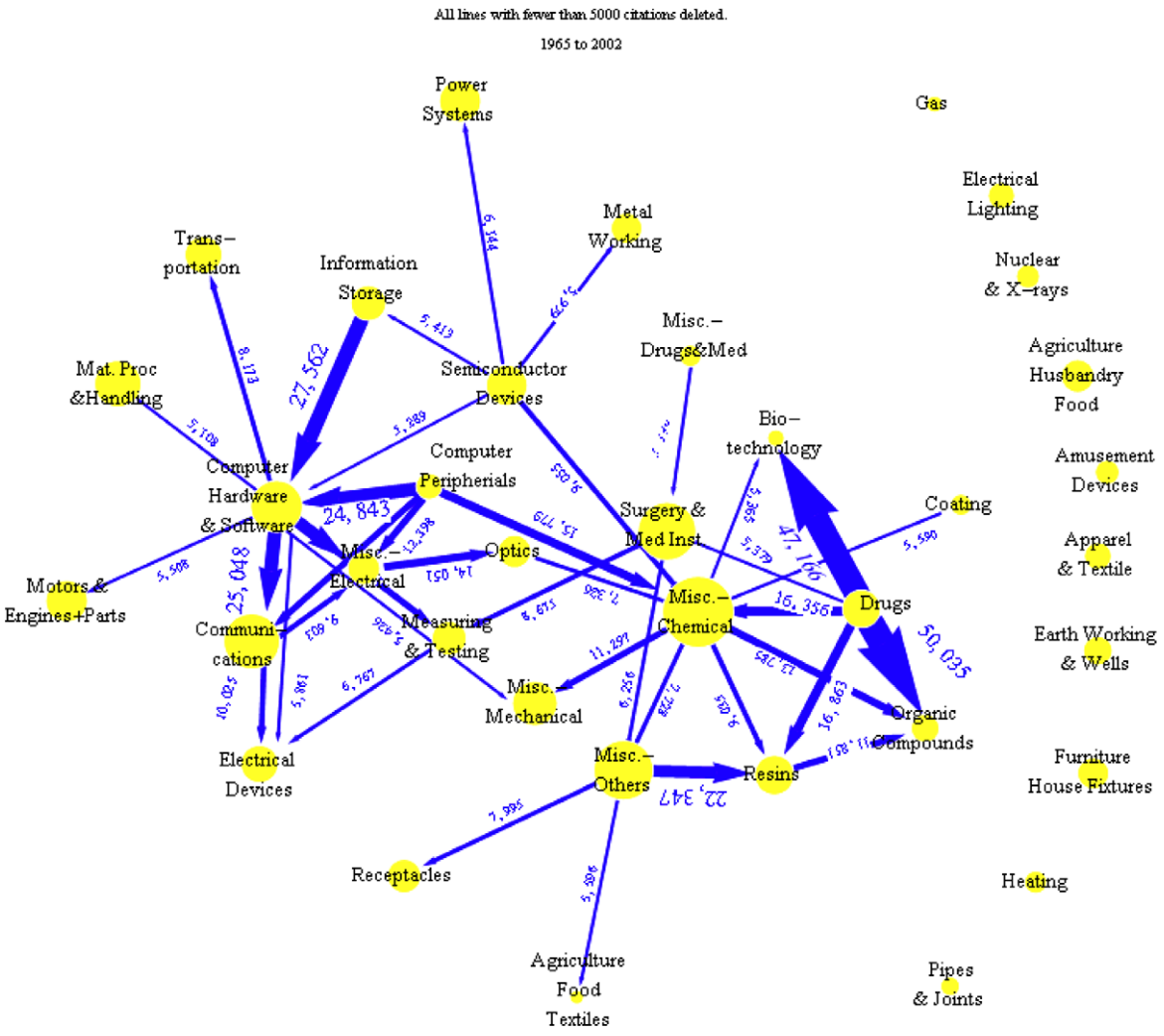

Fig. 8. Net citations between technology categories.

All lines with fewer than 1000 citations deleted. Each line = 1000 citations.

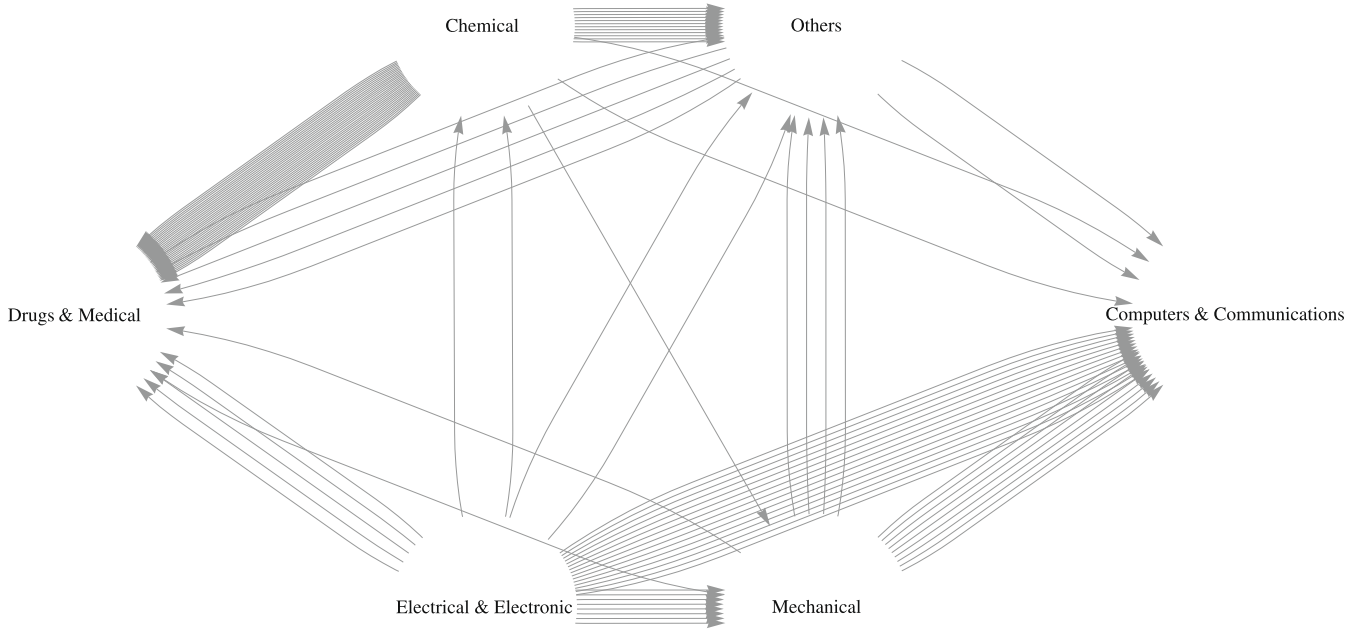

Fig. 9. Net citations between technology categories, 1965–2002.

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Table 2
Total backwards-, per-citation disequilibrium rates, by 2-digit HJT technology category, 1975–2002. Sorted by intra-category-disequilibrium rates

2-Digit patent category	32 Surgery and Med Inst.	62 Amusement Devices	64 Earth Working and Wells	61 Agriculture, Husbandry, Food	46 Semi-conductor Devices	63 Apparel and Textile	31 Drugs	55 Trans-portation	53 Motors and Engines + Parts	65 Furniture, House Fixtures	39 Miscellaneous-Drugs and Med	24 Infor-mation Storage	42 Electrical Lighting	21 Communi-cations	68 Recep-tacles	54 Optics	66 Heating	23 Computer Peripherals	13 Gas
32 Surgery and Med Inst.	**0.785**	−0.009	−0.013	−0.019	−0.028	−0.008	−0.027	−0.028	−0.029	−0.013	0.021	−0.024	−0.014	−0.043	−0.011	−0.021	−0.011	−0.014	−0.003
62 Amusement Devices	−0.027	**0.779**	−0.012	−0.016	−0.028	−0.010	−0.039	−0.018	−0.034	−0.013	−0.007	−0.021	−0.013	−0.041	−0.012	−0.020	−0.012	−0.001	−0.004
64 Earth Working and Wells	−0.030	−0.010	**0.767**	−0.008	−0.029	−0.014	−0.038	−0.010	−0.021	−0.017	−0.007	−0.024	−0.016	−0.042	−0.017	−0.023	−0.009	−0.015	−0.002
61 Agriculture, Husbandry, Food	−0.026	−0.007	−0.004	**0.736**	−0.029	−0.013	−0.020	−0.022	−0.032	−0.011	−0.007	−0.024	−0.015	−0.047	0.022	−0.023	0.000	−0.015	−0.003
46 Semiconductor Devices	−0.030	−0.010	−0.013	−0.020	**0.727**	−0.015	−0.039	−0.029	−0.036	−0.020	−0.007	0.011	−0.003	−0.041	−0.019	−0.020	−0.010	−0.012	−0.004
63 Apparel and Textile	−0.004	−0.006	−0.012	−0.017	−0.028	**0.703**	−0.039	−0.018	−0.033	−0.008	−0.002	−0.024	−0.014	−0.048	−0.004	−0.022	−0.011	−0.015	−0.004
31 Drugs	0.007	−0.010	−0.012	0.002	−0.028	−0.015	**0.701**	−0.029	−0.035	−0.016	0.001	−0.024	−0.016	−0.050	−0.017	−0.023	−0.012	−0.015	−0.004
55 Transportation	−0.030	−0.007	−0.006	−0.017	−0.028	−0.007	−0.039	**0.678**	−0.008	0.002	−0.007	−0.024	−0.014	−0.041	−0.009	−0.022	−0.010	−0.015	−0.004
53 Motors and Engines + Parts	−0.022	−0.010	−0.009	−0.018	−0.028	−0.014	−0.039	−0.006	**0.677**	−0.017	−0.006	−0.024	−0.014	−0.048	−0.018	−0.023	−0.008	−0.015	−0.001
65 Furniture, House Fixtures	−0.014	−0.007	−0.011	−0.013	−0.028	−0.006	−0.037	0.000	−0.029	**0.673**	−0.005	−0.023	−0.015	−0.045	0.008	−0.022	−0.010	−0.015	−0.004
39 Miscellaneous-Drugs and Med	**0.168**	−0.009	−0.012	−0.019	−0.028	−0.006	−0.020	−0.028	−0.031	−0.017	**0.667**	−0.024	−0.014	−0.049	−0.014	−0.016	−0.012	−0.014	−0.004
24 Information Storage	−0.030	−0.009	−0.013	−0.020	0.002	−0.015	−0.039	−0.028	−0.035	−0.019	−0.007	**0.660**	−0.015	−0.029	−0.017	−0.014	−0.012	0.002	−0.004
42 Electrical Lighting	−0.027	−0.009	−0.013	−0.018	−0.009	−0.014	−0.039	−0.025	−0.033	−0.018	−0.006	−0.022	**0.656**	−0.024	−0.016	0.006	−0.009	−0.003	−0.004
21 Communications	−0.026	−0.009	−0.012	−0.019	−0.024	−0.015	−0.039	−0.024	−0.034	−0.018	−0.007	−0.018	−0.007	**0.643**	−0.018	−0.004	−0.012	−0.003	−0.004
68 Receptacles	−0.020	−0.008	−0.012	0.004	−0.028	−0.006	−0.038	−0.018	−0.035	0.001	−0.006	−0.023	−0.015	−0.049	**0.629**	−0.022	−0.010	−0.015	−0.004
54 Optics	−0.028	−0.010	−0.013	−0.020	−0.025	−0.015	−0.039	−0.027	−0.035	−0.019	−0.003	−0.014	0.010	−0.005	−0.017	**0.619**	−0.009	0.004	−0.004
66 Heating	−0.028	−0.010	−0.010	−0.008	−0.024	−0.014	−0.039	−0.025	−0.025	−0.017	−0.007	−0.024	−0.013	−0.049	−0.015	−0.019	**0.613**	−0.015	0.006
23 Computer Peripherals	−0.025	−0.002	−0.013	−0.020	−0.016	−0.015	−0.039	−0.028	−0.034	−0.019	−0.005	0.008	0.004	0.036	−−0.018	0.018	−0.012	**0.603**	−0.004
13 Gas	−0.021	−0.010	−0.010	−0.016	−0.028	−0.015	−0.039	−0.026	−0.024	−0.019	−0.007	−0.022	−0.015	−0.050	−0.015	−0.023	0.006	−0.015	**0.594**
22 Computer Hardware and Software	−0.025	−0.008	−0.012	−0.019	−0.021	−0.014	−0.039	−0.015	−0.021	−0.019	−0.006	0.025	−0.015	0.061	−0.018	−0.016	−0.011	0.016	−0.004
45 Power Systems	−0.027	−0.010	−0.012	−0.019	−0.009	−0.014	−0.039	−0.016	−0.005	−0.016	−0.007	−0.015	−0.008	−0.031	−0.017	−0.019	−0.001	−0.012	−0.001
41 Electrical Devices	−0.027	−0.010	−0.012	−0.019	0.004	−0.013	−0.039	−0.026	−0.032	−0.017	−0.007	−0.011	−0.008	−0.010	−0.015	−0.021	−0.009	−0.013	−0.004
51 Mat. Proc and Handling	−0.022	−0.009	−0.007	−0.012	−0.024	−0.008	−0.037	−0.017	−0.029	−0.012	−0.004	−0.019	−0.015	−0.046	0.003	−0.015	−0.009	−0.014	−0.002
15 Resins	−0.023	−0.008	−0.009	−0.017	−0.028	−0.015	−0.016	−0.027	−0.035	−0.019	−0.003	−0.024	−0.016	−0.050	−0.017	−0.022	−0.012	−0.014	−0.004
43 Measuring and Testing	−0.011	−0.009	−0.008	−0.018	−0.018	−0.015	−0.039	−0.024	−0.022	−0.019	−0.005	−0.018	−0.010	−0.010	−0.017	−0.010	−0.010	−0.012	−0.002
19 Miscellaneous-Chemical	−0.020	−0.010	−0.008	−0.015	−0.017	−0.013	−0.032	−0.025	−0.029	−0.018	−0.006	−0.022	−0.012	−0.048	−0.009	−0.016	−0.005	−0.012	0.005
59 Miscellaneous-Mechanical	−0.019	−0.005	−0.008	−0.015	−0.028	−0.010	−0.039	−0.009	−0.003	−0.010	−0.006	−0.020	−0.015	−0.040	−0.009	−0.017	−0.009	−0.008	−0.003
52 Metal Working	−0.023	−0.009	−0.009	−0.018	−0.009	−0.012	−0.039	−0.022	−0.023	−0.014	−0.005	−0.017	−0.014	−0.046	−0.008	−0.019	0.001	−0.011	−0.003
67 Pipes and Joints	−0.021	−0.008	0.010	−0.017	−0.028	−0.007	−0.039	−0.015	0.001	−0.007	−0.006	−0.023	−0.015	−0.048	−0.010	−0.022	−0.006	−0.015	−0.003
44 Nuclear and X-rays	−0.015	−0.009	−0.012	−0.019	−0.013	−0.014	−0.039	−0.026	−0.034	−0.018	−0.006	−0.014	0.005	−0.024	−0.015	0.006	−0.008	−0.009	−0.003
69 Miscellaneous-Others	−0.020	−0.004	−0.007	−0.014	−0.024	−0.006	−0.037	−0.015	−0.019	0.001	−0.005	−0.020	−0.011	−0.043	0.004	−0.016	−0.003	−0.012	0.000
49 Miscellaneous-Elec	−0.022	−0.009	−0.012	−0.009	−0.022	−0.014	−0.039	−0.024	−0.033	−0.017	−0.006	−0.004	−0.004	0.003	−0.015	0.030	−0.003	0.003	−0.004
14 Organic Compounds	−0.029	−0.010	−0.012	−0.015	−0.028	−0.015	0.068	−0.029	−0.036	−0.020	−0.007	−0.024	−0.016	−0.051	−0.019	−0.023	−0.012	−0.015	−0.003
33 Biotechnology	−0.021	−0.010	−0.011	−0.007	−0.028	−0.015	0.018	−0.029	−0.035	−0.019	−0.005	−0.024	−0.016	−0.050	−0.016	−0.022	−0.011	−0.015	−0.004
11 Agriculture, Food, Textiles	−0.018	−0.010	−0.011	−0.006	−0.028	0.018	−0.003	−0.027	−0.034	−0.017	−0.006	−0.024	−−0.016	−0.050	−0.016	−0.023	−0.011	−0.014	−0.001
12 Coating	−0.020	−0.009	−0.006	−0.014	−0.002	−0.011	−0.028	−0.027	−0.033	−0.015	−0.002	−0.021	−0.009	−0.048	−0.013	−0.015	−0.006	−0.008	−0.002

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2-Digit patent category		22 Computer Hardware and Software	45 Power Systems	41 Electrical Devices	51 Material Procedures and Handling	15 Resins	43 Measuring and Testing	19 Miscellaneous-Chemical	59 Miscellaneous-Mechanical	52 Metal Working	67 Pipes and Joints	44 Nuclear and X-rays	69 Miscellaneous-Others	49 Miscellaneous-Elec	14 Organic Compounds	33 Biotech-nology	11 Agriculture, Food, Textiles	12 Coating
32	Surgery and Med Inst.	−0.037	−0.031	−0.028	−0.039	−0.026	−0.010	−0.075	−0.035	−0.024	−0.005	−0.007	−0.061	−0.019	−0.031	−0.009	−0.005	−0.012
62	Amusement Devices	−0.029	−0.033	−0.028	−0.039	−0.026	−0.025	−0.087	−0.018	−0.022	−0.006	−0.013	−0.024	−0.017	−0.032	−0.011	−0.007	−0.013
64	Earth Working and Wells	−0.038	−0.032	−0.028	−0.014	−0.020	−0.014	−0.058	−0.017	−0.017	0.016	−0.013	−0.039	−0.023	−0.028	−0.010	−0.006	−0.006
61	Agriculture, Husbandry, Food	−0.040	−0.034	−0.029	−0.015	-0.026	−0.025	-0.058	-0.028	-0.026	-0.006	-0.014	−0.049	−0.012	−0.022	−0.004	0.000	−0.009
46	Semiconductor Devices	−0.018	0.000	0.004	−0.041	−0.031	−0.016	−0.040	−0.044	−0.002	−0.008	−0.007	−0.068	−0.017	−0.031	−0.011	−0.007	0.006
63	Apparel and Textile	−0.040	−0.031	−0.027	−0.022	−0.030	−0.026	−0.077	−0.029	−0.023	−0.003	−0.013	−0.032	−0.022	−0.032	−0.011	0.009	−0.011
31	Drugs	−0.041	−0.035	−0.032	−0.037	0.032	−0.026	−0.032	-0.044	−0.027	−0.008	−0.012	−0.070	−0.024	**0.159**	**0.105**	0.008	0.000
55	Transportation	−0.029	−0.016	−0.027	−0.026	−0.030	−0.024	-0.080	−0.002	−0.023	−0.003	−0.013	−0.036	−0.021	−0.032	−0.011	−0.007	−0.014
53	Motors and Engines + Parts	−0.025	0.000	−0.026	−0.040	−0.032	−0.019	−0.075	−0.002	−0.019	0.006	−0.014	−0.036	−0.022	−0.032	−0.011	−0.007	−0.014
65	Furniture, House Fixtures	−0.041	−0.027	−0.027	−0.030	−0.031	−0.027	−0.085	−0.015	−0.024	0.001	−0.013	0.018	−0.021	−0.032	−0.011	−0.007	−0.011
39	Miscellaneous-Drugs and Med	−0.038	−0.033	−0.030	−0.029	−0.008	−0.023	−0.079	−0.040	−0.019	−0.005	-0.012	−0.062	−0.020	−0.030	−0.006	−0.004	−0.003
24	Information Storage	**0.131**	−0.023	−0.013	−0.038	−0.032	−0.023	−0.089	−0.039	−0.022	−0.008	−0.008	−0.070	−0.001	−0.032	−0.011	−0.007	−0.014
42	Electrical Lighting	−0.040	−0.014	−0.010	−0.044	−0.032	−0.020	−0.068	−0.042	−0.024	−0.007	0.002	−0.058	−0.007	−0.032	−0.011	−0.007	−0.008
21	Communications	0.041	−0.023	−0.002	−0.043	−0.032	−0.010	−0.089	−0.038	−0.026	−0.008	−0.007	−0.069	0.007	−0.032	−0.011	−0.007	−0.014
68	Receptacles	−0.041	−0.033	−0.029	0.000	−0.030	−0.027	−0.053	−0.023	−0.019	−0.005	−0.013	−0.021	−0.022	−0.032	−0.010	−0.007	−0.012
54	Optics	−0.031	−0.027	−0.028	−0.028	−0.030	−0.008	−0.047	−0.038	−0.026	−0.008	0.011	−0.054	0.004	−0.031	−0.011	−0.007	−0.008
66	Heating	−0.039	−0.003	−0.025	−0.036	−0.032	−0.024	−0.036	−0.030	−0.001	−0.002	−0.010	−0.024	−0.012	−0.032	−0.010	−0.007	−0.009
23	Computer Peripherals	**0.159**	−0.019	−0.020	−0.041	−0.029	−0.019	−0.019	−0.022	−0.024	−0.008	−0.004	−0.049	0.050	−0.031	−0.011	−0.007	−0.006
13	Gas	−0.042	−0.018	−0.029	−0.029	−0.024	−0.018	0.091	−0.030	−0.022	−0.006	−0.013	−0.032	−0.023	−0.028	−0.010	−0.002	−0.007
22	Computer Hardware and Software	**0.593**	−0.019	−0.020	−0.038	−0.033	0.002	−0.089	−0.027	−0.025	−0.008	−0.005	−0.068	0.015	−0.032	−0.010	−0.007	−0.014
45	Power Systems	−0.022	**0.587**	0.017	−0.040	−0.031	−0.010	−0.068	−0.029	−0.009	−0.006	−0.010	−0.059	−0.006	−0.031	−0.011	−0.007	−0.012
41	Electrical Devices	−0.030	0.021	**0.578**	−0.044	−0.030	−0.015	−0.082	−0.038	−0.007	−0.003	−0.012	−0.062	0.001	−0.032	−0.011	−0.007	−0.012
51	Mat. Proc and Handling	−0.037	−0.029	−0.029	**0.560**	−0.013	−0.022	−0.032	−0.006	−0.004	−0.004	−0.011	−0.027	−0.019	−0.030	−0.010	−0.003	−0.003
15	Resins	−0.042	−0.034	−0.030	−0.028	**0.557**	−0.028	−0.018	−0.040	−0.026	−0.008	−0.014	−0.030	−0.024	0.021	0.001	0.002	0.018
43	Measuring and Testing	−0.003	−0.003	−0.003	−0.036	−0.032	**0.554**	−0.059	−0.037	−0.019	−0.006	0.029	−0.056	−0.011	−0.032	−0.009	−0.007	−0.012
19	Miscellaneous-Chemical	−0.040	−0.026	−0.028	−0.020	−0.002	−0.018	**0.550**	−0.029	−0.016	−0.006	−0.009	−0.037	−0.020	−0.008	0.001	0.000	0.005
59	Miscellaneous-Mechanical	−0.025	−0.023	−0.025	−0.008	−0.029	−0.023	−0.069	**0.547**	−0.012	0.002	−0.009	−0.031	−0.020	−0.026	−0.011	−0.007	−0.009
52	Metal Working	−0.038	−0.002	−0.001	0.007	−0.029	−0.019	-0.039	−0.005	**0.525**	0.003	−0.011	−0.028	−0.009	−0.031	−0.011	−0.007	0.000
67	Pipes and Joints	−0.042	−0.028	−0.013	−0.025	−0.029	−0.022	−0.068	0.000	0.000	**0.525**	−0.012	−0.006	−0.022	−0.032	−0.011	−0.006	−0.012
44	Nuclear and X-rays	−0.021	−0.025	−0.024	−0.036	−0.032	0.049	−0.062	−0.035	−0.021	−0.006	**0.524**	−0.068	−0.003	−0.031	−0.009	−0.007	−0.011
69	Miscellaneous-Others	−0.035	−0.026	−0.023	−0.014	0.004	−0.020	−0.032	−0.016	−0.013	0.003	−0.012	**0.497**	−0.018	−0.029	−0.010	0.003	0.008
49	Miscellaneous-Elec	−0.003	−0.005	0.005	−0.037	−0.032	−0.015	−0.072	−0.039	−0.011	−0.007	−0.005	−0.058	**0.495**	−0.032	−0.011	−0.007	−0.008
14	Organic Compounds	−0.042	−0.035	−0.032	−0.046	0.023	−0.028	−0.019	−0.042	−0.028	−0.008	−0.014	−0.077	−0.025	**0.444**	0.009	0.010	−0.009
33	Biotechnology	−0.040	−0.035	−0.032	−0.044	0.001	−0.022	0.004	−0.045	−0.027	−0.008	−0.012	−0.076	−0.024	0.000	**0.385**	−0.001	−0.012
11	Agriculture, Food, Textiles	−0.041	−0.033	−0.031	−0.018	0.023	−0.027	0.008	−0.039	−0.026	−0.007	−0.013	−0.004	−0.024	0.058	−0.004	**0.382**	0.009
12	Coating	−0.041	−0.026	−0.027	−0.012	0.056	−0.024	0.055	−0.026	−0.005	−0.006	−0.010	0.025	−0.015	−0.014	−0.009	0.008	**0.372**
																	0.515	0.649
																	Average:	0.582

Values greater than 0.1 are highlighted.

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Table 3
Total forwards-, per-citation disequilibrium rates, by 2-digit HJT technology category, 1975–2002. Sorted by intra-category-disequilibrium rates.

2-Digit patent category	62 Amusement Devices	32 Surgery and Med Inst.	63 Apparel and Textile	64 Earth Working and Wells	42 Electrical Lighting	53 Motors and Engines + Parts	61 Agriculture, Husbandry, Food	55 Trans-portation	46 Semi-conductor Devices	65 Furniture, House Fixtures	68 Recep-tacles	66 Heating	21 Communi-cations	54 Optics	24 Infor-mation Storage	39 Misc.-Drugs and Med	41 Electrical Devices	45 Power Systems	15 Resins	13 Gas	59 Misc.-Mechanical	33 Biotech-nology	44 Nuclear and X-rays	22 Computer Hardware and Software	67 Pipes and Joints
62 Amusement Devices	**0.770**	−0.026	−0.010	−0.012	−0.014	−0.035	−0.015	−0.022	−0.028	−0.015	−0.013	−0.012	−0.040	−0.021	−0.022	−0.006	−0.030	−0.033	−0.022	−0.004	−0.024	−0.010	−0.013	−0.024	−0.007
32 Surgery and Med Inst.	−0.010	**0.767**	−0.010	−0.013	−0.015	−0.031	−0.019	−0.028	−0.028	−0.015	−0.015	−0.012	−0.046	−0.022	−0.023	0.027	−0.030	−0.033	−0.029	−0.004	−0.038	−0.009	−0.011	−0.036	−0.007
63 Apparel and Textile	−0.007	0.004	**0.725**	−0.012	−0.013	−0.033	−0.016	−0.010	−0.028	−0.006	−0.001	−0.011	−0.047	−0.022	−0.023	−0.001	−0.028	−0.031	−0.031	−0.004	−0.030	−0.011	−0.013	−0.036	−0.003
64 Earth Working and Wells	−0.010	−0.029	−0.015	**0.703**	−0.016	−0.028	−0.010	−0.018	−0.028	−0.018	−0.018	−0.010	−0.046	-0.023	−0.024	−0.007	−0.030	−0.033	−0.025	−0.003	−0.032	-0.010	-0.013	−0.035	0.005
42 Electrical Lighting	−0.008	−0.023	−0.013	−0.013	**0.699**	−0.034	−0.018	−0.024	0.004	−0.018	−−0.017	−0.010	−0.012	0.019	−0.022	−0.005	−0.016	−0.015	−0.032	−0.004	−0.042	−0.011	0.004	−0.036	−0.007
53 Motors and Engines + Parts	−0.010	−0.018	−0.015	−0.007	−0.015	**0.693**	−0.018	−0.007	−0.028	−0.016	−0.018	−0.009	−0.048	−0.023	−0.023	−0.006	−0.028	0.000	−0.032	−0.002	−0.001	−0.011	−0.014	−0.010	0.001
61 Agriculture, Husbandry, Food	−0.009	−0.027	−0.014	−0.005	−0.015	−0.033	**0.687**	−0.025	−0.028	−0.014	0.008	−0.007	−0.048	−0.023	−0.024	−0.007	−0.030	−0.034	−0.029	−0.003	−0.036	−0.004	−0.014	−0.039	−0.007
55 Transportation	−0.007	−0.029	−0.010	−0.005	−0.014	−0.006	−0.015	**0.682**	−0.028	0.001	−0.009	−0.011	−0.039	−0.022	−0.024	−0.007	−0.029	−0.016	−0.030	−0.004	−0.012	−0.011	−0.013	−0.006	−0.003
46 Semiconductor Devices	−0.010	−0.030	−0.015	−0.013	−0.007	−0.036	−0.020	−0.029	**0.676**	−0.020	−0.019	−0.011	−0.044	−0.021	0.000	−0.007	−0.002	−0.013	−0.032	−0.004	−0.045	−0.011	−0.008	−0.029	−0.008
65 Furniture, House Fixtures	−0.007	−0.011	−0.007	−0.011	−0.015	−0.030	−0.011	0.002	−0.028	**0.669**	0.004	−0.011	−0.045	−0.022	−0.023	−0.005	−0.028	−0.026	−0.032	−0.004	−0.022	−0.011	−0.013	−0.040	−0.003
68 Receptacles	−0.007	−0.009	−0.005	−0.011	−0.014	−0.034	0.014	−0.016	−0.028	0.005	**0.664**	−0.010	−0.048	−0.020	−0.021	−0.005	−0.026	−0.032	−0.030	−0.003	−0.027	−0.010	−0.012	−0.040	−0.005
66 Heating	−0.010	−0.023	−0.015	−0.009	−0.013	−0.023	0.004	−0.024	−0.023	−0.016	−0.015	**0.663**	−0.048	−0.017	−0.024	−0.007	−0.025	0.007	−0.032	0.006	−0.032	−0.010	−0.009	−0.036	−0.003
21 Communications	−0.009	−0.023	−0.015	−0.011	−0.010	−0.034	−0.019	−0.025	−0.023	−0.018	−0.018	−0.012	**0.655**	−0.005	−0.015	−0.007	−0.012	−0.024	−0.032	−0.004	−0.038	−0.011	−0.008	0.070	−0.008
54 Optics	−0.009	−0.025	−0.015	−0.013	0.003	−0.035	−0.019	−0.027	−0.024	−0.019	−0.017	−0.010	0.007	**0.631**	−0.013	−0.004	−0.029	−0.028	−0.031	−0.004	−0.033	−0.011	0.004	−0.023	−0.008
24 Information Storage	−0.009	−0.030	−0.015	−0.013	−0.015	−0.036	−0.020	−0.028	0.012	−0.019	−0.018	−0.012	−0.038	−0.015	**0.622**	−0.007	−0.017	−0.024	−0.033	−0.004	−0.040	−0.011	−0.009	0.065	−0.008
39 Miscellaneous-Drugs and Med	−0.010	**0.131**	−0.010	−0.013	−0.015	−0.033	−0.020	−0.028	−0.028	−0.017	−0.016	−0.012	−0.049	−0.014	−0.024	**0.622**	−0.031	−0.035	−0.018	−0.004	−0.044	−0.009	−0.013	−0.038	−0.007
41 Electrical Devices	−0.009	−0.023	−0.014	−0.012	−0.007	−0.031	−0.018	−0.025	0.012	−0.017	−0.017	−0.010	0.012	−0.020	−0.005	−0.007	**0.616**	0.026	−0.031	−0.004	−0.037	−0.011	−0.011	−0.016	−0.004
45 Power Systems	−0.010	−0.024	−0.014	−0.012	−0.007	−0.006	−0.019	−0.016	0.006	−0.015	−0.017	−0.002	−0.031	−0.018	−0.014	−0.006	0.018	**0.602**	−0.032	−0.002	−0.032	−0.011	−0.011	−0.014	−0.006
15 Resins	−0.008	−0.017	−0.014	−0.007	−0.015	−0.035	−0.016	−0.026	−0.026	−0.019	−0.017	−0.012	−0.049	−0.021	−0.023	0.001	−0.030	−0.033	**0.598**	−0.003	−0.041	0.002	−0.014	−0.042	−0.007
13 Gas	−0.010	−0.014	−0.014	−0.008	−0.015	−0.020	−0.016	−0.026	−0.027	−0.019	−0.016	0.006	−0.050	−0.022	−0.023	−0.006	−0.031	−0.017	−0.028	**0.585**	−0.033	−0.009	−0.012	−0.040	−0.007
59 Miscellaneous-Mechanical	−0.004	−0.014	−0.011	−0.005	−0.015	−0.002	−0.013	−0.004	−0.027	−0.007	−0.008	−0.009	−0.037	−0.018	−0.019	−0.005	−0.026	−0.020	−0.029	−0.002	**0.575**	−0.011	−0.011	−0.012	0.000
33 Biotechnology	−0.010	−0.012	−0.015	−0.010	−0.016	−0.036	−0.003	−0.029	−0.028	−0.019	−0.016	−0.011	−0.049	−0.022	−0.023	0.000	−0.031	−0.035	0.032	−0.004	−0.046	**0.568**	−0.010	−0.036	−0.008
44 Nuclear and X-rays	−0.009	0.006	−0.014	−0.012	0.003	−0.034	−0.019	−0.025	−0.008	−0.017	−0.017	−0.009	−0.011	0.025	−0.010	−0.005	−0.026	−0.022	−0.032	−0.004	−0.028	−0.009	**0.567**	0.006	−0.007
22 Computer Hardware and Software	−0.008	−0.025	−0.015	−0.012	−0.016	−0.026	−0.019	−0.023	−0.016	−0.020	−0.019	−0.011	0.034	−0.019	0.050	−0.006	−0.026	−0.023	−0.033	−0.004	−0.033	−0.010	−0.010	**0.567**	−0.008
67 Pipes and Joints	−0.007	−0.010	−0.008	0.027	−0.015	0.017	−0.014	−0.010	−0.028	0.002	−0.010	−0.005	−0.047	−0.021	−0.023	−0.003	−0.014	−0.026	−0.031	−0.003	0.005	−0.011	−0.010	−0.041	**0.566**
43 Measuring and Testing	−0.009	0.009	−0.015	−0.006	−0.011	−0.024	−0.018	−0.025	−0.012	−0.019	−0.017	−0.010	−0.008	−0.006	−0.018	−0.005	−0.016	−0.009	−0.032	−0.003	−0.037	−0.008	0.026	0.027	−0.006
19 Miscellaneous-Chemical	−0.010	−0.019	−0.013	−0.008	−0.012	−0.030	−0.013	−0.025	−0.009	−0.018	−0.010	−0.006	−0.047	−0.012	−0.022	−0.005	−0.028	−0.025	−0.005	0.006	−0.035	0.000	−0.010	−0.038	−0.006
51 Mat. Proc and Handling	−0.008	−0.019	−0.009	−0.003	−0.015	−0.030	−0.006	−0.017	−0.023	−0.013	0.004	−0.009	−0.044	−0.013	−0.018	−0.003	−0.029	−0.029	−0.017	−0.002	−0.009	−0.010	−0.011	−0.028	−0.004
31 Drugs	−0.010	−0.010	−0.015	−0.013	−0.016	−0.036	−0.009	−0.029	−0.028	−0.018	−0.018	−0.012	−0.051	−0.023	−0.024	−0.001	−0.032	−0.035	−0.008	−0.004	−0.046	0.006	−0.014	−0.042	−0.008
49 Miscellaneous-Elec	−0.007	−0.018	−0.014	−0.012	−0.007	−0.033	−0.010	−0.024	−0.019	−0.017	−0.017	−0.008	0.032	0.003	0.001	−0.005	−0.003	−0.009	−0.032	−0.004	−0.038	−0.011	−0.003	0.058	−0.007
14 Organic Compounds	−0.010	−0.028	−0.015	−0.011	−0.016	−0.036	−0.009	−0.028	−0.027	−0.020	−0.019	−0.012	−0.050	−0.022	−0.023	−0.006	−0.032	−0.034	0.063	−0.003	−0.038	0.011	−0.014	−0.041	−0.008
52 Metal Working	−0.008	−0.020	−0.013	−0.006	−0.013	−0.023	−0.018	−0.022	0.012	−0.016	−0.009	0.000	−0.045	−0.020	−0.016	−0.003	−0.002	−0.001	−0.029	−0.003	−0.016	−0.010	−0.010	−0.032	0.002
69 Miscellaneous-Others	−0.004	−0.015	−0.007	−0.006	−0.012	−0.019	−0.012	−0.015	−0.022	0.002	−0.002	−0.005	−0.041	−0.015	−0.020	−0.005	−0.024	−0.024	−0.009	−0.001	−0.019	−0.010	−0.012	−0.030	0.000
23 Computer Peripherals	−0.003	−0.028	−0.015	−0.013	−0.008	−0.035	−0.020	−0.028	−0.024	−0.020	−0.019	−0.012	−0.015	−0.003	−0.004	−0.007	−0.030	−0.031	−0.031	−0.004	−0.030	−0.011	−0.011	0.046	−0.008
11 Agriculture, Food, Textiles	−0.010	−0.004	0.022	−0.009	−0.016	−0.034	0.002	−0.025	−0.028	−0.017	−0.015	−0.011	−0.050	−0.022	−0.023	−0.001	−0.030	−0.032	0.023	0.001	−0.040	0.002	−0.014	−0.040	−0.007
12 Coating	−0.009	−0.021	−0.013	−0.004	−0.010	−0.034	−0.013	−0.027	0.018	−0.015	−0.016	−0.008	−0.048	−0.014	−0.022	0.001	−0.025	−0.027	0.041	−0.002	−0.031	−0.009	−0.011	−0.039	−0.006

2-Digit patent category		43 Measuring & Testing	19 Misc. - Chemical	51 Mat. Proc & Handling	31 Drugs	49 Misc. - Electrical	14 Organic Compounds	52 Metal Working	69 Misc. - Others	23 Computer Peripherals	11 Agriculture, Food, Textiles	12 Coating
62	Amusement Devices	−0.025	−0.089	−0.040	−0.038	−0.020	−0.032	−0.024	−0.033	0.000	−0.007	−0.013
32	Surgery and Med Inst.	−0.019	−0.076	−0.041	−0.022	−0.021	−0.032	−0.025	−0.068	−0.014	−0.006	−0.012
63	Apparel and Textile	−0.027	−0.077	−0.025	−0.038	−0.022	−0.032	−0.023	−0.028	−0.014	0.008	−0.010
64	Earth Working and Wells	−0.019	−0.062	−0.031	−0.037	−0.024	−0.030	−0.022	−0.051	−0.015	−0.007	−0.007
42	Electrical Lighting	−0.018	−0.067	-0.044	−0.039	−0.004	−0.031	−0.025	−0.056	0.008	−0.007	−0.007
53	Motors and Engines + Parts	−0.015	−0.075	-0.039	−0.039	-0.022	−0.032	−0.019	−0.044	−0.014	−0.007	−0.014
61	Agriculture, Husbandry, Food	−0.026	−0.068	−0.030	−0.006	−0.011	−0.027	−0.026	−0.058	−0.015	−0.003	−0.011
55	Transportation	−0.023	−0.082	−0.028	−0.039	−0.019	−0.032	−0.021	−0.041	−0.014	−0.007	−0.014
46	Semiconductor Devices	−0.019	−0.060	−0.041	−0.039	−0.020	−0.032	−0.015	−0.072	−0.009	−0.008	−0.002
65	Furniture, House Fixtures	−0.027	−0.085	−0.030	−0.034	−0.021	−0.032	−0.022	0.003	−0.014	−0.007	−0.011
68	Receptacles	−0.025	−0.046	−0.001	−0.036	−0.020	−0.032	−0.017	0.006	−0.014	−0.007	−0.011
66	Heating	−0.023	−0.027	−0.034	−0.038	−0.002	−0.031	0.000	−0.009	−0.014	−0.007	−0.005
21	Communications	−0.011	−0.090	−0.044	−0.039	−0.001	−0.032	−0.026	−0.073	0.008	−0.007	−0.014
54	Optics	−0.013	−0.065	−0.031	−0.039	0.045	−0.032	−0.024	−0.057	0.016	−0.007	−0.010
24	Information Storage	−0.022	−0.088	−0.040	−0.039	−0.006	−0.032	−0.022	−0.072	0.004	−0.007	−0.014
39	Miscellaneous-Drugs and Med	−0.023	−0.083	−0.034	−0.017	−0.021	−0.031	−0.022	−0.070	−0.012	−0.007	−0.007
41	Electrical Devices	−0.003	−0.082	−0.043	−0.039	0.005	−0.032	−0.005	−0.061	−0.008	−0.007	−0.012
45	Power Systems	−0.005	−0.069	−0.040	−0.039	−0.003	−0.032	−0.007	−0.061	−0.007	−0.007	−0.011
15	Resins	−0.028	0.005	−0.018	0.024	−0.024	0.005	−0.025	0.017	−0.013	0.004	0.031
13	Gas	−0.019	0.070	−0.031	−0.037	−0.023	−0.028	−0.023	−0.029	−0.014	−0.004	−0.007
59	Miscellaneous-Mechanical	−0.022	−0.056	−0.006	−0.038	−0.020	−0.030	−0.008	−0.029	−0.004	−0.007	−0.008
33	Biotechnology	−0.020	0.093	−0.042	**0.452**	−0.024	0.038	−0.027	−0.073	−0.014	−0.001	−0.011
44	Nuclear and X-rays	0.068	−0.049	−0.037	−0.034	−0.005	−0.031	−0.021	−0.068	−0.001	−0.007	−0.009
22	Computer Hardware and Software	−0.011	−0.092	−0.044	−0.039	−0.007	−0.032	−0.026	−0.073	0.039	−0.007	−0.015
67	Pipes and Joints	−0.021	−0.066	−0.026	−0.039	−0.022	−0.032	0.002	0.018	−0.014	−0.007	−0.012
43	Measuring and Testing	**0.557**	−0.053	−0.037	−0.037	−0.012	−0.032	−0.020	−0.058	−0.009	−0.007	−0.012
19	Miscellaneous-Chemical	−0.018	**0.556**	−0.019	−0.021	−0.018	−0.015	−0.015	−0.032	−0.001	−0.001	0.009
51	Mat. Proc and Handling	−0.021	−0.031	**0.555**	−0.032	−0.018	−0.031	−0.002	−0.022	−0.012	−0.003	−0.002
31	Drugs	−0.028	−0.073	−0.045	**0.547**	−0.025	0.041	−0.028	−0.077	−0.015	−0.001	−0.010
49	Miscellaneous-Elec	−0.015	−0.077	−0.039	−0.038	**0.521**	−0.032	−0.015	−0.061	0.034	−0.007	−0.009
14	Organic Compounds	−0.028	0.037	−0.044	**0.235**	−0.024	**0.518**	−0.027	−0.067	−0.014	0.019	0.000
52	Metal Working	−0.017	−0.041	0.000	−0.038	−0.005	−0.032	**0.505**	−0.030	−0.012	−0.007	0.001
69	Miscellaneous-Others	−0.020	−0.035	−0.016	−0.035	−0.016	−0.030	−0.013	**0.482**	−0.008	−0.001	0.007
23	Computer Peripherals	−0.025	−0.080	−0.045	−0.039	−0.001	−0.032	−0.024	−0.071	**0.458**	−0.007	−0.009
11	Agriculture, Food, Textiles	−0.026	0.035	−0.015	0.036	−0.023	0.035	−0.025	0.066	−0.012	**0.430**	0.026
12	Coating	−0.023	0.035	−0.012	−0.013	−0.013	−0.024	−0.006	0.034	−0.005	0.001	**0.363**
											0.529	0.640
											Average:	0.584

Values greater than 0.1 are highlighted.

Table 4
Backwards-citations per-patent, from and to each 2-digit HJT technology category, 1975–2002. Sorted by intra-category-citation rates.

2-Digit patent category	32 Surgery and Med Inst.	39 Misc.-Drugs and Med	22 Computer Hardware and Software	46 Semi-conductor Devices	21 Communi-cations	24 Infor-mation Storage	64 Earth Working and Wells	62 Amuse-ment Devices	23 Computer Peripherals	13 Gas	68 Recep-tacles	61 Agriculture, Husbandry, Food	19 Misc.-Chemical	54 Optics	45 Power Systems	53 Motors and Engines + Parts	65 Furniture, House Fixtures	15 Resins
32 Surgery and Med Inst.	**9.684**	0.334	0.065	0.006	0.097	0.004	0.006	0.011	0.012	0.019	0.097	0.017	0.246	0.025	0.052	0.084	0.080	0.081
39 Miscellaneous-Drugs and Med	**1.702**	**5.790**	0.034	0.002	0.021	0.002	0.005	0.008	0.007	0.004	0.044	0.004	0.146	0.064	0.020	0.040	0.027	0.213
22 Computer Hardware and Software	0.052	0.007	**5.767**	0.070	**1.016**	0.445	0.014	0.024	0.279	0.002	0.008	0.010	0.060	0.062	0.150	0.138	0.007	0.002
46 Semiconductor Devices	0.003	0.000	0.170	**5.362**	0.074	0.247	0.001	0.001	0.022	0.002	0.004	0.001	0.394	0.020	0.256	0.003	0.001	0.017
21 Communications	0.037	0.002	0.611	0.031	**5.114**	0.047	0.009	0.012	0.089	0.001	0.007	0.007	0.050	0.143	0.090	0.012	0.013	0.009
24 Information Storage	0.006	0.001	**1.173**	0.208	0.147	**4.620**	0.000	0.006	0.112	0.002	0.012	0.001	0.046	0.063	0.086	0.004	0.006	0.003
64 Earth Working and Wells	0.005	0.000	0.027	0.001	0.052	0.001	**4.527**	0.005	0.001	0.013	0.014	0.071	0.218	0.002	0.021	0.088	0.019	0.075
62 Amusement Devices	0.022	0.003	0.075	0.001	0.059	0.014	0.008	**4.469**	0.078	0.002	0.040	0.020	0.047	0.019	0.017	0.010	0.037	0.038
23 Computer Peripherals	0.036	0.014	**1.423**	0.088	0.619	0.223	0.001	0.056	**4.361**	0.002	0.008	0.002	0.539	0.290	0.121	0.017	0.005	0.025
13 Gas	0.072	0.003	0.005	0.004	0.009	0.015	0.022	0.001	0.003	**4.351**	0.032	0.026	**1.360**	0.004	0.128	0.089	0.010	0.062
68 Receptacles	0.068	0.008	0.006	0.002	0.013	0.009	0.006	0.018	0.003	0.006	**4.293**	0.156	0.284	0.010	0.018	0.009	0.136	0.020
61 Agriculture, Husbandry, Food	0.023	0.001	0.012	0.001	0.021	0.001	0.047	0.016	0.002	0.007	0.218	**4.011**	0.200	0.003	0.011	0.020	0.046	0.035
19 Miscellaneous-Chemical	0.069	0.007	0.014	0.069	0.020	0.012	0.029	0.004	0.019	0.062	0.065	0.033	**4.005**	0.042	0.061	0.043	0.013	0.190
54 Optics	0.017	0.023	0.066	0.020	0.275	0.058	0.000	0.005	0.110	0.002	0.015	0.002	0.290	**3.789**	0.050	0.006	0.004	0.015
45 Power Systems	0.021	0.002	0.120	0.120	0.121	0.051	0.006	0.004	0.016	0.019	0.012	0.004	0.166	0.026	**3.733**	0.186	0.025	0.012
53 Motors and Engines + Parts	0.044	0.006	0.089	0.002	0.017	0.001	0.019	0.002	0.002	0.017	0.006	0.009	0.105	0.003	0.183	**3.669**	0.016	0.005
65 Furniture, House Fixtures	0.088	0.008	0.006	0.001	0.034	0.005	0.010	0.017	0.001	0.002	0.145	0.034	0.056	0.005	0.045	0.036	**3.662**	0.008
15 Resins	0.046	0.025	0.002	0.005	0.010	0.001	0.022	0.017	0.007	0.005	0.012	0.016	0.481	0.006	0.009	0.003	0.003	**3.653**
55 Transportation	0.005	0.001	0.066	0.001	0.052	0.001	0.036	0.017	0.001	0.004	0.053	0.017	0.082	0.007	0.100	0.140	0.112	0.016
42 Electrical Lighting	0.016	0.005	0.011	0.104	0.141	0.010	0.001	0.009	0.062	0.002	0.015	0.008	0.143	0.154	0.115	0.016	0.009	0.006
31 Drugs	0.173	0.037	0.006	0.003	0.005	0.002	0.004	0.001	0.001	0.002	0.010	0.103	0.296	0.002	0.002	0.002	0.017	0.302
63 Apparel and Textile	0.123	0.022	0.011	0.001	0.015	0.002	0.004	0.021	0.001	0.002	0.072	0.012	0.086	0.006	0.022	0.015	0.053	0.015
49 Miscellaneous-Elec	0.052	0.010	0.252	0.044	0.344	0.126	0.004	0.011	0.116	0.003	0.026	0.067	0.153	0.336	0.197	0.021	0.018	0.008
43 Measuring and Testing	0.110	0.012	0.219	0.058	0.232	0.033	0.030	0.007	0.014	0.013	0.013	0.010	0.207	0.073	0.180	0.078	0.004	0.006
41 Electrical Devices	0.021	0.001	0.067	0.173	0.216	0.066	0.005	0.003	0.009	0.001	0.022	0.007	0.076	0.011	0.301	0.020	0.013	0.013
69 Miscellaneous-Others	0.057	0.009	0.039	0.023	0.045	0.019	0.032	0.035	0.017	0.022	0.126	0.034	0.348	0.041	0.054	0.094	0.113	0.203
51 Mat. Proc and Handling	0.045	0.016	0.029	0.024	0.029	0.023	0.030	0.009	0.006	0.011	0.114	0.041	0.333	0.041	0.034	0.037	0.039	0.104
59 Miscellaneous-Mechanical	0.060	0.004	0.091	0.006	0.058	0.022	0.026	0.030	0.038	0.010	0.052	0.025	0.142	0.032	0.065	0.173	0.054	0.022
66 Heating	0.011	0.001	0.017	0.023	0.012	0.001	0.013	0.002	0.001	0.052	0.022	0.058	0.299	0.020	0.162	0.052	0.014	0.005
67 Pipes and Joints	0.057	0.009	0.002	0.002	0.016	0.003	0.134	0.011	0.001	0.006	0.055	0.018	0.163	0.006	0.044	0.212	0.073	0.026
44 Nuclear and X-rays	0.085	0.004	0.120	0.087	0.152	0.052	0.007	0.006	0.033	0.008	0.020	0.006	0.189	0.163	0.060	0.010	0.012	0.007
52 Metal Working	0.033	0.011	0.021	0.088	0.023	0.032	0.018	0.008	0.016	0.006	0.050	0.008	0.256	0.018	0.150	0.056	0.025	0.016
33 Biotechnology	0.058	0.011	0.014	0.003	0.007	0.002	0.010	0.002	0.001	0.006	0.018	0.080	0.609	0.004	0.004	0.003	0.004	0.211
12 Coating	0.067	0.029	0.010	0.164	0.019	0.015	0.042	0.006	0.045	0.017	0.034	0.033	0.911	0.047	0.056	0.017	0.027	0.541
11 Agriculture, Food, Textiles	0.065	0.006	0.007	0.001	0.004	0.002	0.011	0.003	0.004	0.015	0.016	0.070	0.529	0.003	0.013	0.010	0.013	0.283
14 Organic Compounds	0.005	0.002	0.001	0.002	0.001	0.000	0.004	0.000	0.001	0.004	0.001	0.017	0.285	0.001	0.002	0.001	0.001	0.206

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2-Digit patent category	55 Trans-portation	42 Electrical Lighting	31 Drugs	63 Apparel and Textile	49 Miscella-neous-Elec	43 Measuring and Testing	41 Electrical Devices	69 Misc.-Others	51 Mat. Proc and Handling	59 Misc.-Mechanical	66 Heating	67 Pipes and Joints	44 Nuclear and X-rays	52 Metal Working	33 Biotech-nology	12 Coating	11 Agriculture, Food, Textiles	14 Organic Compounds
32 Surgery and Med Inst.	0.009	0.022	0.151	0.093	0.068	0.215	0.048	0.254	0.103	0.135	0.015	0.035	0.088	0.050	0.027	0.032	0.030	0.010
39 Miscellaneous-Drugs and Med	0.004	0.022	0.169	0.079	0.039	0.048	0.014	0.177	0.163	0.060	0.003	0.028	0.020	0.079	0.039	0.102	0.029	0.013
22 Computer Hardware and Software	0.125	0.012	0.003	0.011	0.364	0.273	0.113	0.136	0.087	0.173	0.009	0.001	0.089	0.031	0.007	0.007	0.002	0.002
46 Semiconductor Devices	0.002	0.095	0.002	0.001	0.057	0.087	0.255	0.106	0.052	0.016	0.014	0.001	0.056	0.185	0.001	0.149	0.001	0.006
21 Communications	0.037	0.064	0.001	0.006	0.238	0.136	0.220	0.098	0.034	0.062	0.004	0.004	0.058	0.016	0.001	0.006	0.001	0.002
24 Information Storage	0.002	0.009	0.001	0.002	0.160	0.038	0.128	0.081	0.071	0.052	0.000	0.003	0.045	0.040	0.002	0.009	0.001	0.002
64 Earth Working and Wells	0.109	0.001	0.005	0.007	0.009	0.084	0.020	0.255	0.197	0.171	0.017	0.141	0.009	0.062	0.007	0.053	0.009	0.022
62 Amusement Devices	0.063	0.019	0.002	0.031	0.047	0.022	0.022	0.332	0.050	0.161	0.002	0.016	0.011	0.032	0.002	0.010	0.003	0.002
23 Computer Peripherals	0.008	0.139	0.002	0.004	0.532	0.068	0.083	0.235	0.052	0.171	0.003	0.002	0.076	0.028	0.002	0.065	0.006	0.005
13 Gas	0.021	0.007	0.004	0.007	0.013	0.075	0.019	0.366	0.138	0.122	0.133	0.018	0.014	0.046	0.008	0.057	0.038	0.027
68 Receptacles	0.069	0.009	0.008	0.066	0.019	0.013	0.023	0.404	0.316	0.156	0.013	0.023	0.010	0.062	0.006	0.019	0.007	0.002
61 Agriculture, Husbandry, Food	0.036	0.008	0.104	0.015	0.070	0.016	0.014	0.178	0.175	0.096	0.067	0.013	0.005	0.014	0.037	0.033	0.039	0.051
19 Miscellaneous-Chemical	0.022	0.023	0.049	0.016	0.030	0.066	0.026	0.281	0.175	0.108	0.042	0.016	0.034	0.074	0.075	0.123	0.046	0.146
54 Optics	0.009	0.151	0.002	0.005	0.172	0.121	0.022	0.168	0.118	0.052	0.016	0.004	0.152	0.015	0.002	0.043	0.002	0.003
45 Power Systems	0.078	0.049	0.001	0.010	0.115	0.108	0.291	0.140	0.047	0.107	0.065	0.013	0.028	0.115	0.001	0.021	0.004	0.004
53 Motors and Engines + Parts	0.115	0.009	0.001	0.006	0.014	0.047	0.028	0.237	0.040	0.231	0.021	0.072	0.004	0.044	0.000	0.006	0.002	0.001
65 Furniture, House Fixtures	0.151	0.008	0.015	0.051	0.021	0.006	0.027	0.534	0.095	0.166	0.011	0.051	0.010	0.023	0.001	0.022	0.005	0.002
15 Resins	0.012	0.002	0.145	0.006	0.004	0.003	0.010	0.323	0.125	0.038	0.002	0.003	0.003	0.014	0.074	0.205	0.062	0.331
55 Transportation	**3.554**	0.011	0.001	0.044	0.022	0.023	0.024	0.234	0.113	0.226	0.010	0.029	0.010	0.027	0.000	0.004	0.003	0.002
42 Electrical Lighting	0.018	**3.509**	0.002	0.010	0.092	0.044	0.113	0.128	0.020	0.022	0.015	0.005	0.089	0.024	0.001	0.035	0.001	0.002
31 Drugs	0.001	0.001	**3.436**	0.003	0.004	0.011	0.002	0.057	0.052	0.013	0.001	0.000	0.010	0.005	0.537	0.068	0.072	0.888
63 Apparel and Textile	0.049	0.010	0.002	**3.333**	0.015	0.010	0.025	0.236	0.121	0.081	0.005	0.024	0.007	0.024	0.000	0.018	0.078	0.002
49 Miscellaneous-Elec	0.031	0.078	0.002	0.011	**3.306**	0.083	0.232	0.157	0.073	0.049	0.061	0.006	0.059	0.108	0.001	0.042	0.002	0.002
43 Measuring and Testing	0.026	0.032	0.003	0.005	0.076	**3.249**	0.159	0.146	0.066	0.052	0.012	0.014	0.242	0.048	0.012	0.015	0.003	0.002
41 Electrical Devices	0.014	0.041	0.001	0.012	0.135	0.073	**3.228**	0.108	0.020	0.044	0.014	0.028	0.014	0.112	0.001	0.018	0.002	0.002
69 Miscellaneous-Others	0.074	0.026	0.013	0.051	0.039	0.049	0.049	**3.171**	0.189	0.168	0.049	0.060	0.014	0.083	0.004	0.126	0.056	0.019
51 Mat. Proc and Handling	0.060	0.007	0.012	0.039	0.028	0.034	0.017	0.288	**3.156**	0.213	0.017	0.020	0.017	0.123	0.004	0.064	0.022	0.008
59 Miscellaneous-Mechanical	0.106	0.008	0.004	0.027	0.027	0.030	0.035	0.271	0.209	**3.107**	0.018	0.052	0.027	0.084	0.001	0.030	0.005	0.030
66 Heating	0.018	0.017	0.001	0.006	0.063	0.024	0.033	0.292	0.058	0.080	**3.106**	0.033	0.022	0.135	0.003	0.031	0.003	0.002
67 Pipes and Joints	0.079	0.008	0.001	0.051	0.017	0.035	0.109	0.443	0.131	0.271	0.037	**3.079**	0.013	0.163	0.001	0.020	0.006	0.002
44 Nuclear and X-rays	0.015	0.114	0.003	0.007	0.122	0.428	0.045	0.083	0.065	0.061	0.023	0.015	**2.971**	0.041	0.013	0.022	0.002	0.004
52 Metal Working	0.032	0.010	0.002	0.017	0.073	0.044	0.137	0.243	0.246	0.187	0.059	0.052	0.017	**2.476**	0.001	0.070	0.003	0.004
33 Biotechnology	0.001	0.002	0.350	0.001	0.005	0.042	0.002	0.039	0.027	0.007	0.004	0.000	0.016	0.005	**2.426**	0.017	0.043	0.195
12 Coating	0.009	0.042	0.067	0.025	0.062	0.026	0.031	0.650	0.217	0.126	0.037	0.011	0.028	0.141	0.010	**2.343**	0.094	0.111
11 Agriculture, Food, Textiles	0.009	0.001	0.187	0.168	0.005	0.009	0.006	0.399	0.152	0.036	0.004	0.005	0.005	0.011	0.035	0.121	**1.977**	0.459
14 Organic Compounds	0.001	0.001	0.395	0.000	0.001	0.001	0.001	0.020	0.007	0.018	0.001	0.000	0.001	0.002	0.074	0.023	0.066	**1.761**

This table is calculated using total (inter-plus intra-category) backwards-citations, but the numbers are very similar, and the ordering identical, when using total forward-citations simply because the totals over the 28 year time period encompass almost the entire dataset of citations.
Values greater than one are highlighted.

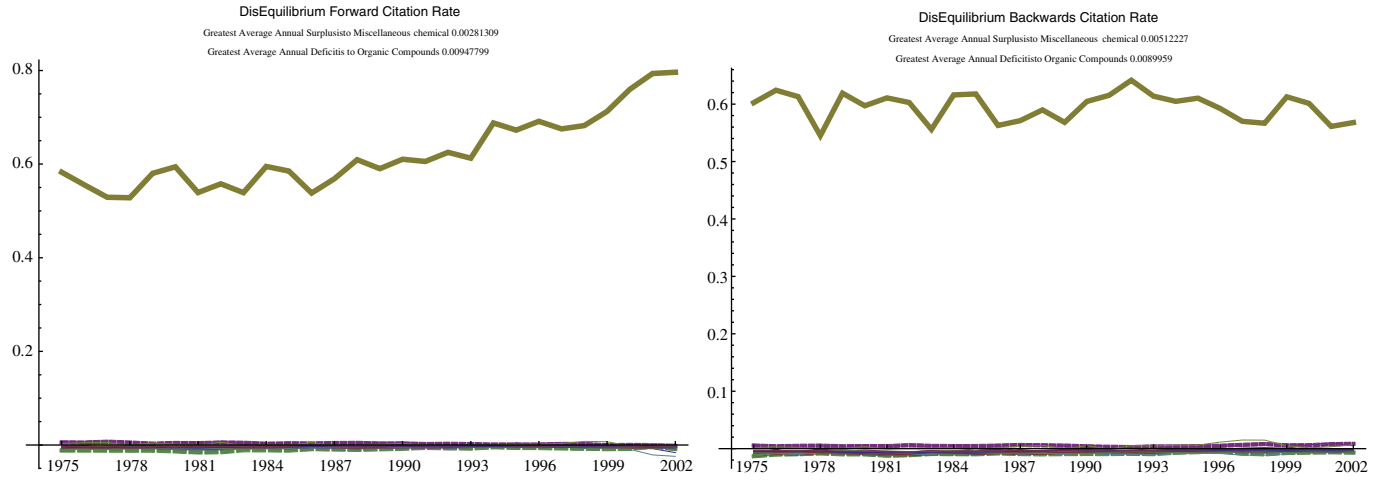

Fig. 10. Disequilibrium forwards- and backwards-citation rates for *Gas (13)*.

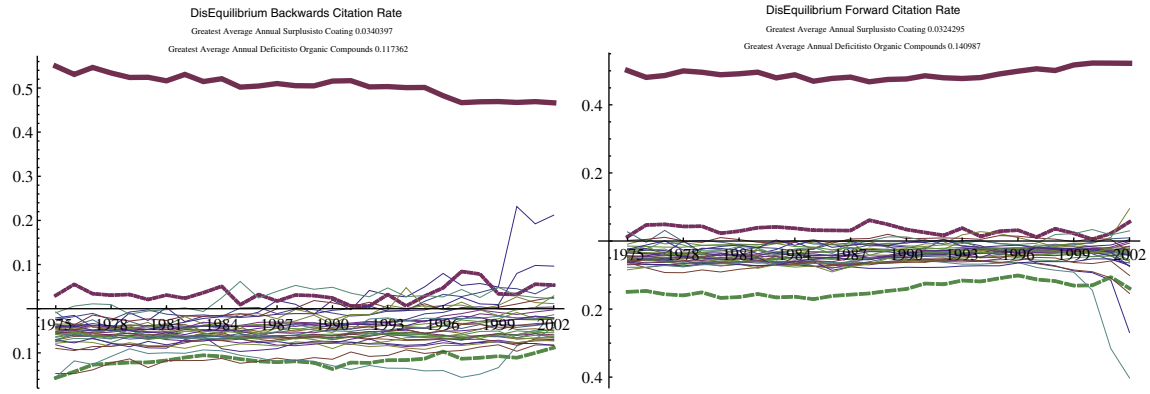

Fig. 11. Citation rates for *Miscellaneous-Others* (69).

and N_k is the number of patents in the kth category, and N is the total number of patents in all categories.

For a technology category to be adequately defined we would expect for the actual number of citations to itself (the 'intra-' citation rate) to be higher than the expected intra-citation rate, and, in general, for the inter-citation rates (to other categories) to be lower than the expected inter-citation rates. These statistics can be calculated for both backwards- and forwards-citations. Tables 2–4 provide the average differences of these ratios. Most all of the disequilibrium intra-citation rates (the diagonal values) are 50% points greater than their expected values, while, on average, the inter-citation rates are all a few percentage points lower than their expected values – usually negative. Thus, at the level of aggregation of the 2-digit HJT technology categories, it doesn't ever appear that any of the categories are redundant or could be combined.

5. Generality and originality: backwards- and forwards-citation rates over time

These relationships are pretty stable over time and across all 2-digit patent categories, for both backwards- and forwards-citations. Some of the most stable disequilibrium forwards- (and backwards-) citation rates over time are for *Gas*, in Fig. 10[4]. It has its largest average annual forwards-disequilibrium surplus with *Misc. Chemicals*, with a 28-year average of 0.00281309 and the greatest annual average deficit with *Organic Compounds* of −0.00947799. Here one can see that *Gas* cites itself about 65% more often than would be expected from purely random citation behaviour, starting with disequilibrium of about 60% in 1975 and ending in 2002 with almost 80%. This upward trend implies that *Gas* has become relatively more self-dependent.

At the same time, however, *Gas* is also making forwards-citations to the other categories at fairly constant rates that appear to not be significantly different from zero. Comparing this to the backwards-citation rates over time reveals even more stability over time, with no visible trend for the intra-citation disequilibrium values. And again, it has its highest average disequilibrium citation rate with *Miscellaneous-Chemical*, and it's lowest with *Organic Compounds*.

Since we are interpreting backwards-citation rates as indicators of generality, and forwards-rates as indicators of originality, what can we say then about *Gas*? Since these are all relative values, normalized by the total number of citations made, one can only infer that *Gas* is becoming relatively more self-original over time – i.e. whatever originality it produces is increasingly going to itself, and decreasingly going to the other technologies. Similarly, over the years, *Gas* has remained relatively constant in self-generality – it has taken itself as its source of innovations at about the same rate as it has taken the other categories.

As an interesting counter-example, compare the graphs for *Miscellaneous-Others* (Fig. 11). *Misc.-Others* is one of the three major

[4] The numbers in parenthesis in these and subsequent figures are the technology categories as used in HJT [16].

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'miscellaneous' categories, presumably absorbing patents that either fit nowhere, or lie on the boundaries of two or more other categories. It is immediately evident that, as one would expect, *Misc.-Others* has much more interaction with the rest of the patent population than does *Gas*, being most closely aligned with *Coatings* in both backwards- and forwards-citations. But just like *Gas*, it does not exhibit radical changes in any of its relative rates over time.

Most of the categories that one would assume to be less exciting or less innovative exhibit behaviour similar to that of *Gas* and *Misc.-Others*: e.g. *Agriculture*, *Coatings*, *Measuring and Testing, Metal Working, Material Processes, Earth Working, Amusement Devices, Furniture, Heating, etcetera.* They all maintain mostly constant intra- and inter-citation rates over time. On the other hand, the more volatile behaviour is to be seen in areas that one usually associates with rapid innovation in the last few decades, particularly in all of the *Chemical, the Drugs and Medical, and the Computer & Communications* categories.

One of these interesting exceptions where disequilibrium citation rates change dramatically over time can be seen for the *Organic Compounds* category in Fig. 12. Here, during the late 1970's, *Organic Compounds* had its actual forwards-citation rate from *Drugs* around 60% points higher than would be expected. And in fact the difference is actually higher than the intra-citation disequilibrium rate from *Organic Compounds* to itself for a year or two. The inverse of this pattern is not exactly repeated for the *Drugs* graph, which behaves much more like the usual cases. For *Drugs*, there is a slow upward trend in self-originality, along with a significant upward increase in the relative originality being supplied from *Organic Compounds,* at the expense of all other categories. One may conclude that *Drugs* is becoming more reliant on *Organic Compounds,* but, seemingly paradoxically, *Organic Compounds* is slowly becoming independent of *Drugs* for its innovations.

Another striking case of volatile change is between *Biotechnology* and *Drugs* (Fig. 13). In 1975, *Biotechnology* has an intra-forwards-citation rate 60% higher than expected, but this difference steadily falls to barely 5% in 1999, while *Drugs* moves in to supply an increasing percent of the innovation. Then suddenly in the three years from 2000 to 2002, *Biotechnology's* intra-forwards-citation rate shoots backwards to almost 100%, displacing everything else. What happened in 2000? Was there a regime shift at the USPTO to redefine *Biotechnology* patents as a class? Did Biotech firms suddenly change their behaviour? Or is this a true explosion in the originality of Biotech?

This pattern is also repeated in *Biotechnology's* backwards-citation graph – shooting from ~55% above the expected intra-citation rate to more than 80%. This is all the more striking since backwards-citations are final. Not only does *Biotechnology* get more original, it is also getting more general.

Also of interest is that all four subcategories of *Computers and Communications* (*Communications,* Computer Hardware and Software, Computer Peripherals, and *Information Storage)* begin to suffer erratic behaviour in all or some of their intra-, inter-, backwards-, and forwards-citation rates from around 1995 onwards.

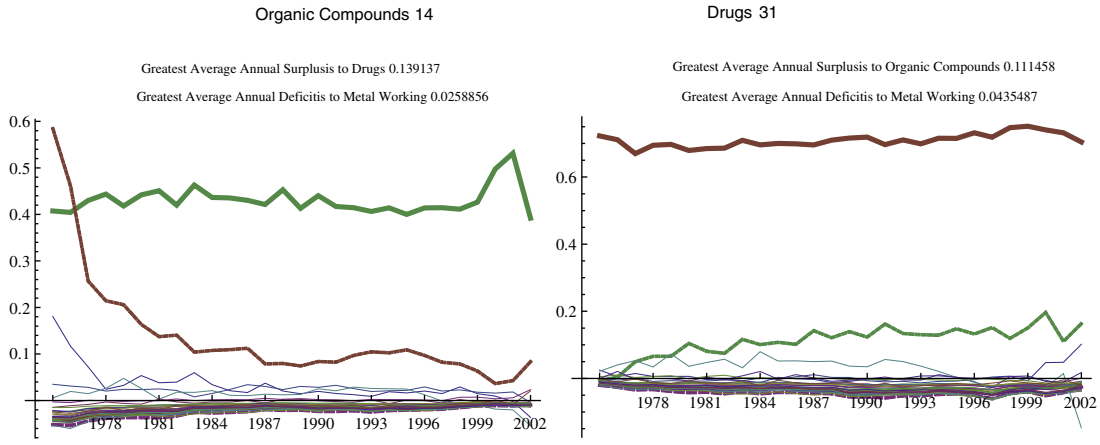

Fig. 12. Disequilibrium forwards-citation rates for *Organic Compounds (14)* and *Drugs (31).*

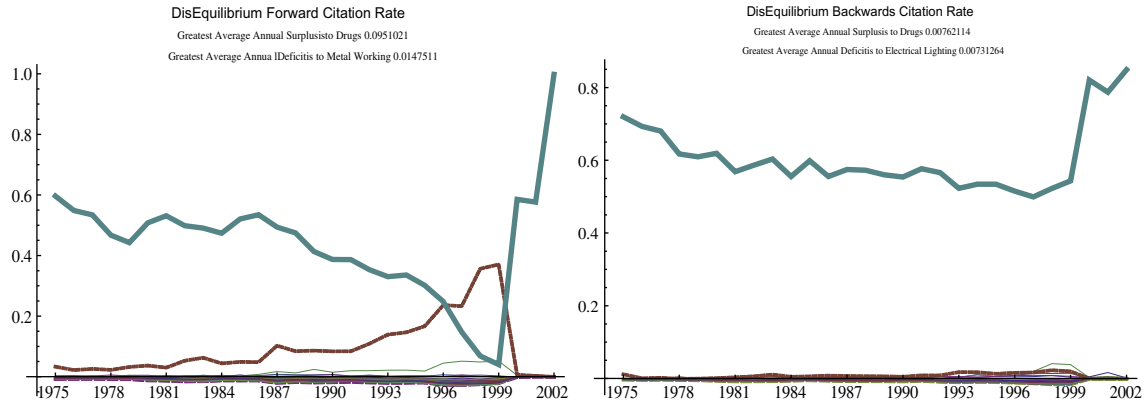

Fig. 13. Disequilibrium forwards- and backwards-citation rates for *Biotechnology (33).*

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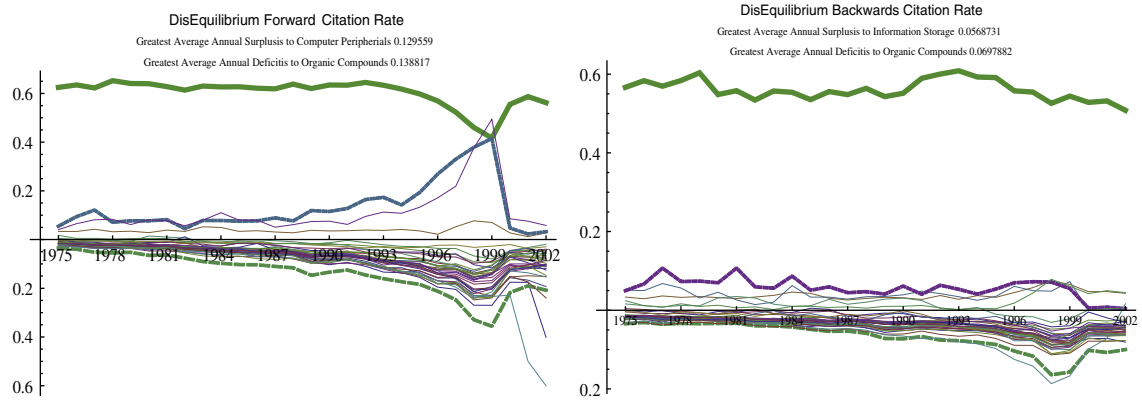

Fig. 14. Disequilibrium forward- and backwards-citation rates for *Computer Hardware and Software (22).*

The most dramatic of these is for the forwards-citations of *Computer Hardware and Software* (Fig. 14). Here two other categories *Computer Peripherals and Communications* slowly expand their influence until suddenly, again after reaching a peak in 1999, they are expurgated and return to pre-1975 levels. It is easy to imagine that the computer revolutions brought the categories together as they enjoyed increasing cross pollination. Apparently in 1999, however, something came along to reinforce rigor in either the classifications of patents or their citations.

6. Productivity: citations-per-patent

While volatility of the relative ratios of intra- or inter-citations to total citations in the *Computers and Communications* and *Drugs and Medical* categories might suggest innovation or competition, the numbers of citations-per-patent implies that these categories are generally more 'productive'. For both backwards- and forwards-citations, these categories have the highest citation-per-patent ratios over the last ten years (Fig. 15). For backwards-

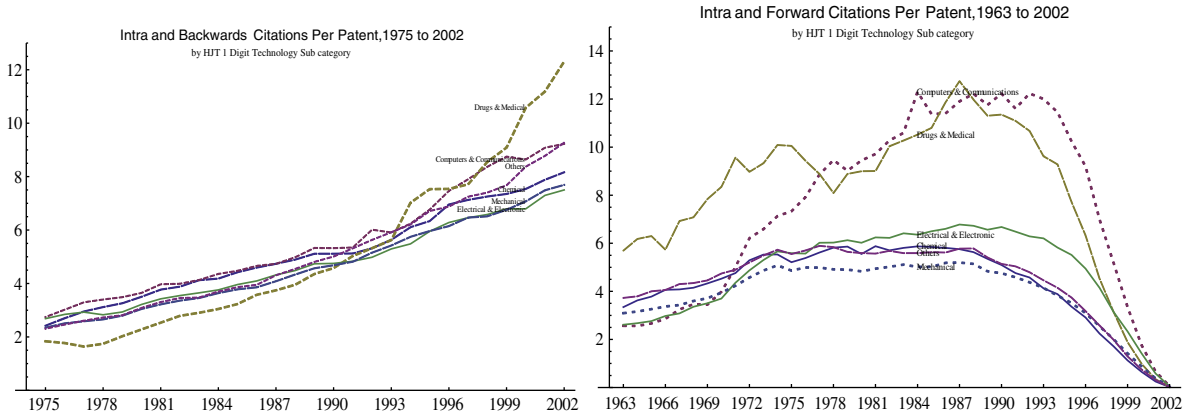

Fig. 15. Citations-per-patent, by HJT 1-digit technology subcategory.

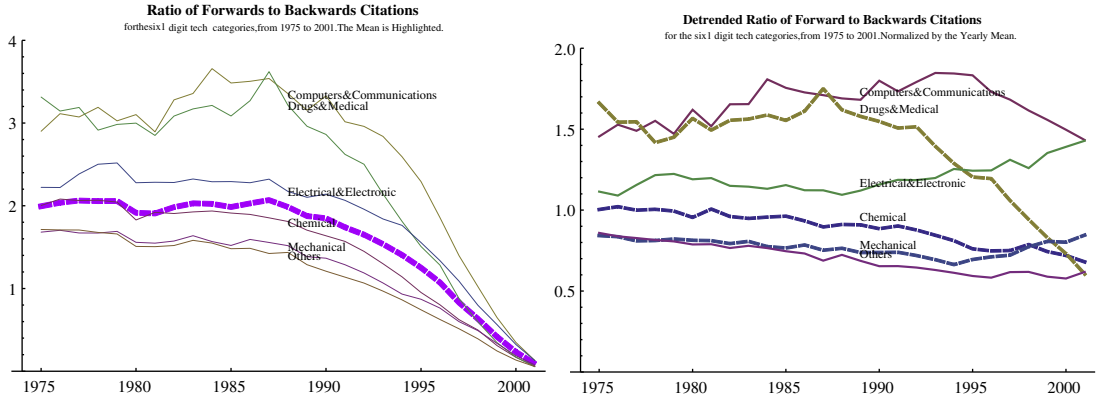

Fig. 16. Ratios of forwards- to backwards-citations by 1-digit tech category, 1975–2001.

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citations, the interpretation would be that a higher ratio implies a greater synthesis of prior knowledge, while for forwards-citations we could imagine that a higher per-patent citation ratio implies higher innovation.

One could also imagine that technology categories with decreasing ratios of forwards- to backwards-citations were experiencing an expansion in their field as fewer inputs in the form of backwards-citations are being converted into more and more outputs, in the form of forwards-citations. Fig. 16a illustrates these trends, however it is clear that the truncation effect for forwards-citations does not make this a straightforward task. However it is also apparent that this ratio is less curved than the forwards- (and intra-) citations per-patent series.

As one goes further back in time, of course, the truncation effect decreases. Fig. 16b detrends these series with the mean. Now it is possible to infer that the *Chemical, Mechanical,* and *Others* categories are less-and-less productive, while *Electrical and Electronic* is more-and-more so. This decrease in the ratio of forwards- to backwards-citations could occur because patents that cite many prior patents are more likely to be summarizing previous work and not introducing much of anything new – the clichéd 'evolution as opposed to revolution'.

However as noted previously, conclusions of this nature will become less-and-less meaningful the closer we get to the present, due to truncation. Without a model of patent and citation creation, it is impossible to make firm conclusions here. The differences in rates of the collapse of the forwards-citations accounts for the dramatic downturns in both *Computers and Communications* and *Drugs and Medical.*

7. Conclusions

It is presently impossible to directly graph or plot the entire patent citation network of 4 million US patents and 22 million citations. This leaves it up to various statistical analyses to help us visualize it. From what has been presented here it is clear that at the largest scale, the independently determined technology categories do describe the largest structures. And in a fashion similar to the galaxies, solar systems, and planets of the cosmos, each of these super structures appears to be comprised of smaller clumps and thickets which in turn are also comprised of still smaller clumps and thickets. From examples like Figs. 1 and 2, and many years of experience in the field, we know that this clumping continues all the way down to small groups of individual patents in highly specialized fields.

For reasons of either productivity or tradition, all of the technology categories differ in the statistical properties of their patent citation networks. Any inferences of economic value, modeling of patent or citation growth, or predictions of future patent trends will have to account for these differences. Identification of especially active or 'hot' areas of patenting based on the growth of patents or citations would have to take into account historical differences for that or similar technology categories.

Future research could attempt to reduce the amount of data in the network by clumping increasingly larger thickets into single nodes. In this fashion visualization of ever larger portions of the citation universe could be accomplished. Statistical properties of the clumps at various scales could then be compared.

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