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**Working Paper**

## The Demise of Distance? The Declining Role of Physical Distance In Knowledge Transmission

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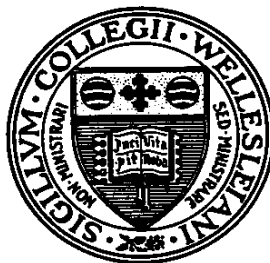
**WORKING PAPER**

**The Demise of Distance?  
The Declining Role of Physical Distance  
In Knowledge Transmission**

by

**Daniel Johnson  
Nalyn Siripong  
and  
Amy Brown**

**Wellesley College Working Paper 2002-06  
September 2002**



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**The Demise of Distance?**  
**The Declining Role of Physical Distance**  
**In Knowledge Transmission**

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**Abstract:**

The economics literature clearly shows that the transmission of knowledge diminishes with physical distance, a factor contributing to industrial clustering. This paper investigates how those distances have stretched over time. We measure the physical distance between collaborating inventors, as well as distances between inventors and the technology cited in their patents. There is an obvious change over time while controlling for other factors, and we present interesting implications about the distance-dissolving effects of the communication revolution: firms and independent inventors benefit in distinctly different ways, while some states and technology classes are obvious winners over their peers. JEL codes: O30, O31, R30, D83.

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# **The Demise of Distance**

## **I. Introduction**

Economics rediscovered geography relatively recently (Krugman, 1991) and since that time there has been a healthy literature estimating the impact of physical distance on knowledge flows (e.g. Jaffe et al., 1993; Jaffe and Trajtenberg, 1999; Keller, 2002). The timing is ironic (as pointed out by Audretsch and Stephan, 1996), coming just as the popular press, and technology experts in particular, herald the “demise of distance” in the flow of technological information (e.g. Gleick, 2002). Surely electronic communication, web-assisted patent searches, cellular phones and teleconferencing have eroded-- if not erased-- the importance of distance just as we economists are measuring it? Should we now expect a growing literature on industrial “de-clustering”?

This paper uses granted U.S. patents to measure the importance of physical distance to knowledge flows. We measure the physical distance between collaborating inventors, as well as distances between inventors and the technology cited in their bibliographies. From these data, we note an obvious change over time while controlling for other factors, and have interesting implications about the distance-dissolving effects of the communication revolution: firms and independent inventors benefit in distinctly different ways, while some states and technology classes are obvious winners over their peers.

## **II. Data**

Every patent includes the names and addresses of all inventors and assignees (usually a firm, but sometimes an individual or government department who retains the

patent rights). We limit our analysis to patents with at sufficient locational information to calculate distances from United States Geological Survey data (i.e. collaboration analysis required at least two inventors with U.S. addresses, while citation analysis required one U.S. address in each of the citing and cited patents). Data availability dictate our observation period (citing and cited patents granted between 1975 and 1999) since previous years are only accessible in paper form<sup>1</sup>. This gives us a full sample of just over half a million patents between 1975 and 1999, with roughly one and a half million collaborative distances and twenty million citation distances. For computational purposes, we used a random sample of every tenth citation (roughly two million observations) for citation analysis.

Despite other valid reasons for the existence of patent citations (e.g. legal documentation of infringement boundaries, or additions by patent examiners for clarification), there is good evidence that the majority reflect a flow of knowledge (Jaffe et al., 2000). Patents themselves can be criticized as an inadequate measure of technological knowledge, but they at least provide a reliable, available source of recorded innovation, all of which pass a benchmark level of novelty and usefulness (Griliches, 1990).

Our goal is to determine whether the distance between creators and recipients of knowledge has changed over time, while controlling for other potentially confounding factors. Thus, gratuitous (or omitted) inventions or patent citations should not affect our primary results, as long as those errors are randomly distributed over different distances across time. We include controls for each patent's assignee (individual, U.S. firm, U.S.

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<sup>1</sup> Thanks to Bronwyn H. Hall, Adam B. Jaffe and Manuel Trajtenberg for their immense effort in making these raw data available at [www.nber.org/patents](http://www.nber.org/patents). All data, except physical location and subsequent

government agency or foreign-owned firm on U.S. soil), technology class (as defined by the U.S. Patent Office), citing-to-cited lag in years, number of claims (as a measure of technological breadth), generality (the range of technology classes to which subsequent citing patents belong) and originality (the range of technology classes from which a patent's citations hail). Our intuition suggests that while controlling for these factors, the coefficient on a trend variable should be strongly positive.

Figure 1 displays the average distances between collaborators, and between citing and cited patents, with trends over time. Notice that the average distance between collaborators has risen by two-thirds in the last quarter century, from 117 miles in 1975 to just shy of 200 miles in 1999. For citations, the pattern is similar, with each decade adding 150 to 200 miles to the average citation distance. Presumably, inventors also become aware of similar technologies close to their location sooner than they learn of distant examples. Thus, citation distance varies with the age of the cited document as well, leading patents granted in 1998 to cite only proximate patents from 1997 but to cite older patents that are further away. The hill-shaped diffusion pattern holds for every year, with earlier years starting at smaller distances, progressing more steeply but reaching a plateau at a lower maximum distance.

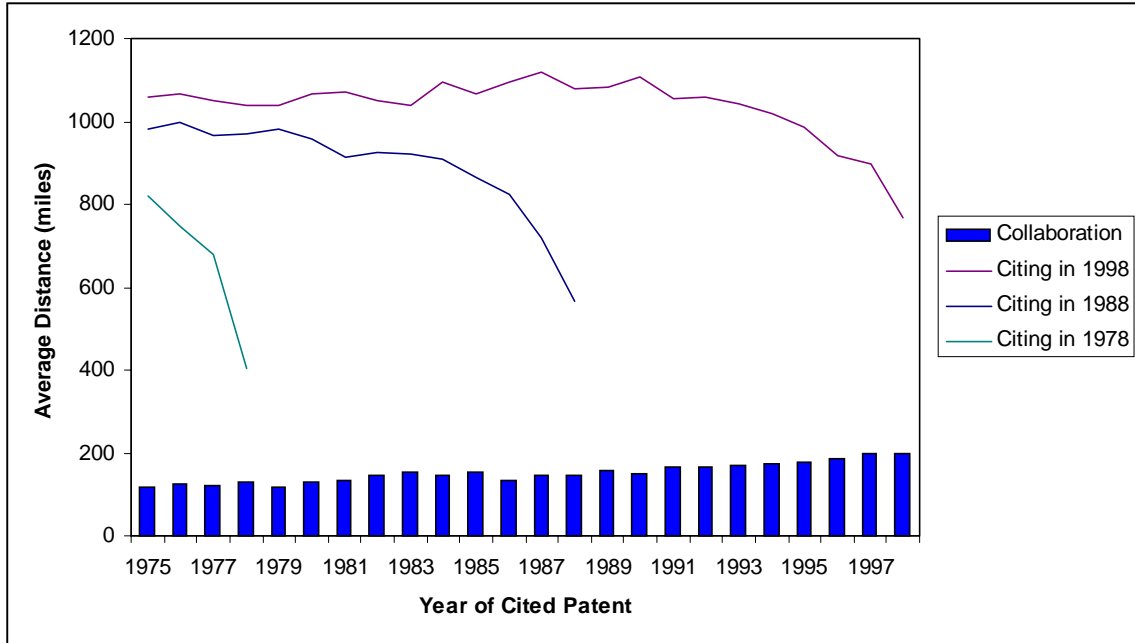
### **III. Estimation and Results**

We estimate a Tobit model, realizing that distance values are always subject to a lower bound of zero and an upper bound limited by the area of analysis (the United States, since we consider only patents with domestic applicants). Regression results are

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distance calculations, are from Hall et al. (2001).

**Figure 1: Average Distances  
between Citations and between Collaborators**



shown in Table 1 for the distance between citations and the distance between collaborators.<sup>2</sup>

The primary results show strong evidence that distance is increasing over time. The time trend is strong, positive and significant, with citation distance rising at an average rate of 6.94 miles per year and collaborator distance rising at an average of 3.80 miles per year, holding other effects constant. Thus, a patent granted in 1991 will tend to rely on patents 140 miles further away than a similar 1971 patent did, with collaborators an average of 76 miles further apart.

<sup>2</sup> Notice that the R-squared values are almost zero, indicating that variation in our chosen variables does not explain the variation in roughly two million observations. We were unsurprised and focus our attention instead on the t-statistics for the variable of interest, namely “trend”.

**Table 1: Tobit Regression of Distance  
between Citations and between Collaborators**

<i>Variable</i>	<b>Citation Tobit</b>		<b>Collaboration Tobit</b>			
	<i>Coefficient</i>	<i>t-statistic</i>	<i>Coefficient</i>	<i>t-statistic</i>		
Trend	6.94	22.38	3.80	23.68		
Lag	4.89	20.07	----	----		
Generality	average	citing class	264.03	21.19	101.10	13.46
		cited class	1066.80	62.11	----	----
	standard deviation	citing class	-121.68	3.43	-223.57	10.46
		cited class	-1464.15	31.35	----	----
	difference	citing class	67.46	20.16	10.24	4.46
		cited class	50.02	11.84	----	----
Originality	average	citing class	268.59	19.40	69.80	8.32
		cited class	103.04	6.59	----	----
	standard deviation	citing class	-633.95	11.62	113.55	3.28
		cited class	1265.14	22.98	----	----
	difference	citing class	178.28	45.81	24.52	10.59
		cited class	-0.75	0.23	----	----
Claim	average	citing class	32.81	45.61	3.62	7.85
		cited class	-40.31	53.85	----	----
	standard deviation	citing class	-3.15	5.6	1.47	4.08
		cited class	1.77	3.03	----	----
	difference	citing class	0.76	13.97	0.66	15.95
		cited class	-1.39	24.55	----	----
Constant	429.17	19.77	-81.22	7.26		
LR chi <sup>2</sup> (20)	71792.17		4456.97			
Pseudo R <sup>2</sup>	0.003		0.0004			

We find intuitive signs on other coefficients as well. Older bibliographic materials (those with a longer lag) are found further away than recent references, adding an average of five miles with every year. In other words, a patent granted in 1999 would cite a 1998 patent instead of a similar 1995 patent only if it is an average of 15 miles closer.

We expect that impressive technological leaps would travel greater distances more easily than marginal innovations. Our results confirm that more general and/or original patents enjoy more distance between citations and collaborators. We capture



some technology-specific effects as well, since patents in more general and/or original technology classes spread more widely, but as one might expect, technologies with greater variability in patent generality or originality have less widespread impact than technologies with more consistent records.

The results are not location-specific within the nation. For example, they are not due to a shift in patenting activity to regions where the distance between population centers is greater. While “regional inversion” of this sort has occurred (see Suarez-Villa, 1993; Johnson 1999), state-specific regressions show similar regression results<sup>3</sup>. For citations, 22 states (accounting for 75 percent of all patenting over the period) have positive and significant trend coefficients, and another 18 (and 18 percent of patenting) have coefficients indistinguishable from zero. For collaborations, the results are even stronger: 27 states with positive and significant trends (representing 81 percent of all patents) and 21 states with no discernible effect (another 17 percent of patents). The most striking counter-example is Idaho, which was among the ten states with the highest average distance between collaborators, and became the state with the shortest average distance between collaborators, all within 25 years. For other states with the most change in average distance, see Table 2.

Naturally, not all technologies shared equally in the demise of distance. Technology-specific regressions<sup>4</sup> for citations show that only one-third of all technology classes (incorporating 38 percent of patents) show a positive trend, and almost one-half of all classes (28 percent of patents) show no significant effect. The stretching of distance is

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<sup>3</sup> Note that Tobit regressions for each state have an upper bound on distance that varies by state.

<sup>4</sup> These regressions are identical to those above, but omit technology-specific variables such as the technology class average and variance in generality and originality. Only trend coefficients are shown but others are available on request.

**Table 2: Groups Most (and Least) Affected by  
Change in the Importance of Distance**

<b>Less Clustered (Greater Distance)</b>			
<i>State</i>		<i>Technology Class</i>	
<i>Citations</i>	<i>Collaboration</i>	<i>Citations</i>	<i>Collaboration</i>
Vermont	Oklahoma	Textile manufacturing	Electrical transmission to vehicles
Georgia	Nebraska	Tool changing	Books, strips and leaves
Hawaii	Kansas	Mechanical guns, projectors	Boots and shoes
Ohio	Missouri	Modulators	Gas separation apparatus
Maine	Georgia	Thermolytic distillation	Chemistry of carbon compounds
<b>More Clustered (Smaller Distance)</b>			
<i>State</i>		<i>Technology Class</i>	
<i>Citations</i>	<i>Collaboration</i>	<i>Citations</i>	<i>Collaboration</i>
Idaho	Idaho	Conveyors, chutes and skids	Wooden receptacles
Alabama	Montana	Gear cutting, milling or planing	Multicellular living organisms
California	Arizona	Single-crystal growth processes	Computer memory
Colorado	-----	Rolls and rollers	Computer processing architecture
Nebraska	-----	Fluid treating apparatus for textiles	Conveyors, chutes and skids

once again more universal for collaborators, as the trend is positive in roughly half of all technology classes (63 percent of patents), and virtually all other technologies showed no significant change over time (leaving five percent of all patents in classes with tighter geographic clustering). Technologies which have become more tightly clustered, along with those which have seen the strongest “de-clustering,” are listed in Table 2.

One portion of Table 2 explains the emphasis on industrial clustering in the recent economics literature. Three very prominent and prolific technologies, subsectors within the computer and biotechnology fields, are among the five sectors that have clustered most heavily over time, swimming against the strong current of larger collaboration distances. However, there is evidence that the broader field of biotechnology is de-clustering, moving toward larger distances between collaborators and citations (Johnson and Mareva, 2002).

Finally, not all types of inventors have been affected similarly. Regressions run separately for four type of assignees--- individuals, U.S.-owned corporations, foreign-owned corporations, and U.S. government--- present some striking differences. The distances between citations increased significantly wherever individuals or U.S. firms were involved, especially for citations *from* individuals. This is almost certainly a direct result of online patent searches, which permit rapid knowledge of similar technology regardless of physical location. It is intuitive that individuals are the largest beneficiaries of this new resource, as larger firms had networks to discover distant technologies even in the absence of government-sponsored online search sites.

Of particular interest is the fact that collaborator distance has risen for firms (whether U.S. or foreign-owned) but made no particular change for other assignees. Presumably, the impact of recent communication advances has benefited the networking ability of firms more strikingly than that of individuals. This trend actually narrows a long-standing gap between firms and individual inventors, who have had a substantially larger distance between collaborators throughout the sample period.

#### **IV. Conclusion**

In an attempt to reconcile the economics literature with the technology literature, we have found strong evidence of a trend towards longer transmission distances of technological information, via patent collaborations and bibliographies. Thus, we paint a picture of general “industrial de-clustering” in information networks. The pull of localized knowledge has weakened markedly, decaying in a slow trend with time.

However, there has been substantial discussion about, and investigation into, the “digital divide” as it separates citizens and students from their peers. Yet those same forces are at work on the inventive process, separating inventors from potentially useful information or productive collaborators. While we have shown that physical distance is diminishing in its impact on the flow of technological information, and on collaborative ventures between co-inventors, we have also shown that the trend is stronger for some states, some technologies, and some types of inventors. Indeed, some cases have reversed the trend, and are still progressing toward more tightly clustered information flows.

There is a role for policy-related research here, to identify the peculiarities about a sector, a type of inventor, or a region, those characteristics which make it more or less amenable to long-distance communication of technological information. With well-directed policy, perhaps we can avoid the obvious tendency for those groups to invent more slowly, transform more slowly, and grow more slowly.

With apologies to Mark Twain, “reports of the demise of distance have been greatly exaggerated.” However, its grip has been gravely weakened.

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