The Measurement and Evaluation of Triple Helix Relations among Universities, Industries, and Governments

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Abstract

University-industry-government relations provide a knowledge infrastructure to knowledge-based innovation systems. This knowledge infrastructure may sustain a triple helix dynamics. Whereas the relations between the institutional spheres can be measured as variables, the dynamics generate a probabilistic entropy. The mutual information among the three triple helix institutions provides us with an indicator of this entropy. When the indicator is negative, the self-organization among the three bi-lateral relations prevails. The different dynamics of the Triple Helix at the global and at the national levels, in different databases, and among world regions, are shown using scientometric data for the representation.

1. Introduction

In 1953, Linus Pauling and Robert B. Corey proposed that DNA was made up of three chains, twisted around each other in ropelike helices (Pauling & Corey, 1953). A few months later, James Watson and Francis Crick proposed the double helix, which was then quickly accepted as the correct structure of DNA (Watson & Crick, 1953). This discovery led to a Nobel Prize (Watson, 1970). Double helices can under circumstances stabilize in a complimentary mode, but triple helices may contain all species of chaotic behaviour (Poincaré, 1905).

One has continued to use triple helix models for studying transition processes, for example, in crystallography and molecular biology. More recently, Richard Lewontin (2000) used the metaphor of a Triple Helix for modeling the relations between genes, organisms, and environments. The Triple Helix is now used as the name of an email enterprise at www.thetriplehelix.com that runs forums on chaotic phenomena in computer games.

In a very different context, Henry Etzkowitz and I introduced a Triple Helix model for the dynamics of university-industry-government relations (Etzkowitz & Leydesdorff, 1995). Our argument was that social configurations cannot be expected to stabilize. A knowledge-based regime of innovations remains in transition. The Triple Helix model is then sufficiently complex to encompass the different species of observable behaviour.

For example, the perspectives of participant-observers who are entrained in co-evolutions of mutual shaping between two helices and their potential lock-in (David, 1985; Arthur, 1988), can be distinguished from the perspective of an external observer. The switch to the external perspective enables the analyst to search for options emerging from the interactions that cannot be perceived from within the coevolution. Using the Triple Helix model, one is able to study specific configuration of university-industry-government relations as instantiations of the Triple Helix dynamics of a knowledge-based innovation system (Leydesdorff & Etzkowitz, 1998).

2. The representation of the triple helix dynamics

Because a Triple Helix system cannot be expected to be stable, one is not able to measure it without first reducing the dynamics to a geometrical representation. One can measure instantiations of a Triple Helix, but how does this measurement of a configuration then relate to the dynamics? The fluxes, however, can be evaluated algorithmically, whereas the measurement provides us with a time-stamped representation.

Goguen and Varela proposed already in 1979 the representation of a Triple Helix for a complex system that can exhibit 'autopoiesis' or self-organization:

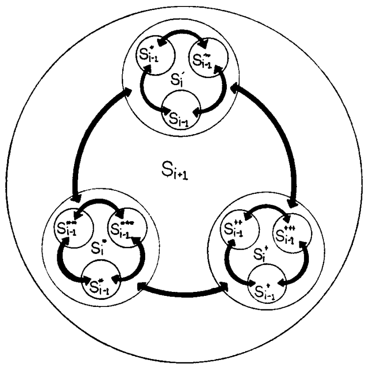


Figure 1.

A schematic depiction of a complex system by Goguen & Varela (1979)

At each step (i-1, i, i+1), the next-order emerging system is composed of interaction effects among the three previous stages of the participating systems. In addition, however, to the recursion of the interaction, a model of university-industry-government relations should encompass the recursive dynamics within each of the helices.

Three helices can first be considered as sets that overlap in the intersections. Let us depict this situation as follows:

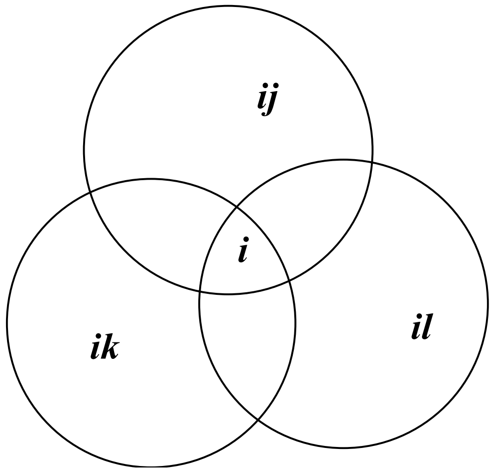


Figure 2

A Triple Helix configuration with positive overlap among the subsystems.

In this configuration, the three helices have a common ground or origin in the overlap area indicated in the representation as *i.* Under conditions, however, this overlap can become zero or even negative. Let me depict this configuration as follows:

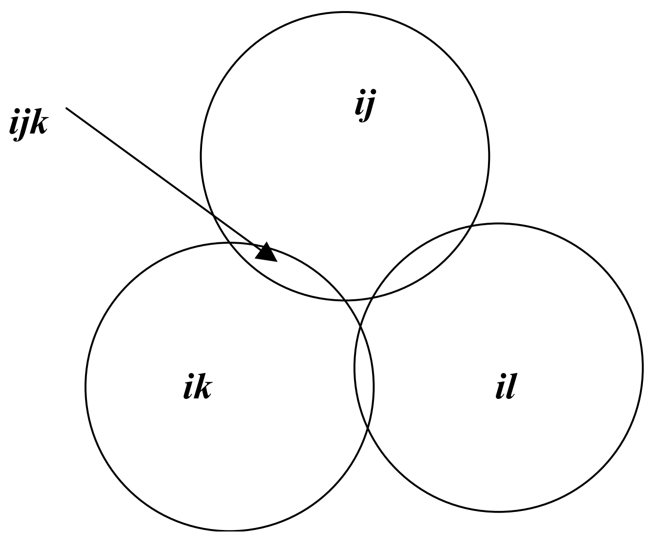


Figure 3: A Triple Helix configuration with negative overlap among the subsystems

In this representation, the three helices have differentiated to such an extent that the communality *i* has been dissolved. This system operates over time in terms of communications at the interfaces (*ijk*). If all the interfaces operate, then one can consider the result as the emergence of a 'hypercycle' (Figure 4). The hypercyclic configuration integrates the three systems in a distributed mode. It fails to integrate completely or one can also say that the integration remains subsymbolic.

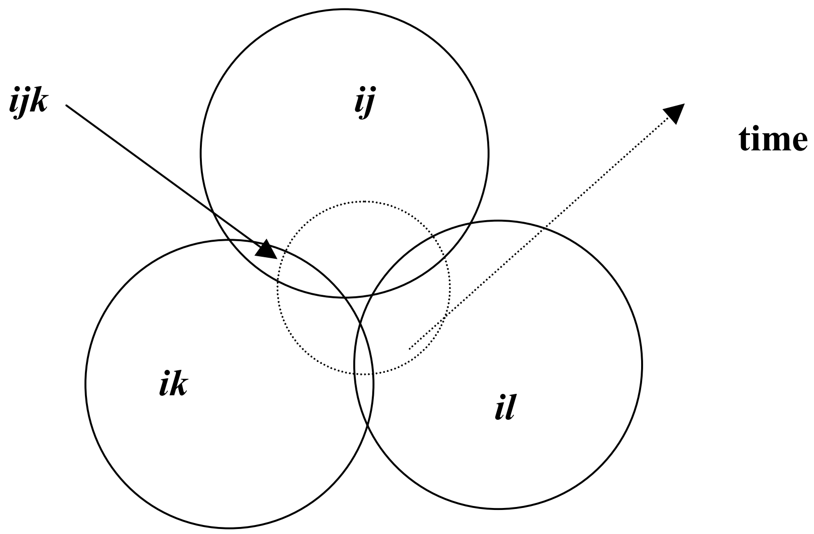


Figure 4

Ex post integration in an 'emerging' hypercycle by recombining different interactions

This configuration can be expected to exhibit 'self-organizing' properties because there is no longer an integration of the various transmissions given in a domain.

Since this domain of integration is failing, each integration leads to a redifferentiation.

Under these conditions the overlap among the sets, that is, the mutual information in three dimensions can become negative (Abramson, 1963). From the perspective of each two systems interfacing, the third dimension remains ‘latent’ as a structural given in the background since the latter system entertains interfaces with each of them. The structural function of the third system remains beyond control for each two relating systems, but the latent network structure reduces the uncertainty.

4. Methodology

Hitherto, we did not have a scientometric indicator to measure Triple Helix configurations. In this study, I propose the mutual information in three dimensions (or the transmission) as an indicator for the dynamics. Unlike co-variation, correlation or co-occurrence measures, the mutual information is defined in the case of interactions among three dimensions.

Triple Helix observations may be measured using one indicator or another (e.g., budgets). The network observations can always be organized in a three-dimensional array using the format exhibited in Figure 5:

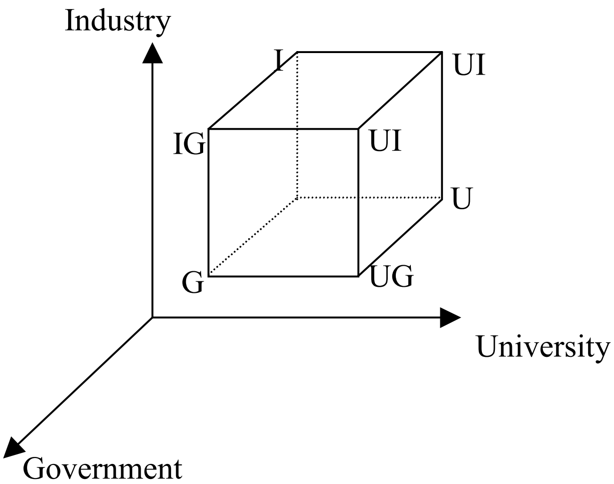


Figure 5

The three-dimensions of measurement in a Triple Helix configuration and their combinations

The measurement does not have to be dichotomous, but can be based on various measurement scales. Different variables can be measured. This may complicate the data gathering, but it does not necessarily change the method of data analysis. When comparing incubators, for example, one is able to count instances that government agencies were involved in the academic-industry relations or not. In other cases, one may be able to measure more precisely, for example, along a measurement scale.

Network data lead to relative frequency distributions (Leydesdorff, 1995). A relative frequency distribution can be rewritten as a probability distribution using:

$$p_i = f_i / \Sigma_i f_i$$

The probabistic entropy of this distribution was defined by Shannon (1948) as:

$$H_i = - \Sigma_i p_i \log(p_i)$$

H can be measured for more dimensions by adding the appropriate normalization for the additional variables, as follows:[1]

$$H_{ij} = - \Sigma_i \Sigma_j p_{ij} \log(p_{ij})$$

The mutual information between two dimensions is then equal to the transmission (T) of the uncertainty (Theil, 1972):

$$T_{ij} = H_i + H_j - H_{ij}$$

Abramson (1963, at p. 129) showed that the transmission in three dimensions can be written as:

$$T_{ijk} = H_i + H_j + H_k – H_{ij} – H_{ik} – H_{jk} + H_{ijk}$$

or in the case of data about university-industry-government (UIG) relations as:

[1] If the two-base is used for the logarithm, the uncertainty (H) is measured in bits of information.

$$T_{UIG} = H_U + H_I + H_G - H_{UI} - H_{IG} - H_{UG} + H_{UIG}$$

Note that the uncertainty of the variables measured in each of the interacting systems (H_U, H_I, and H_G) is reduced by the relations at interfaces between them, but the three-dimensional uncertainty adds positively to the uncertainty that prevails. Because of this alteration of the signs the three-dimensional transmission can also become negative.

Conceptually, the generation of a negative entropy corresponds with the idea of complexity that is contained or 'self-organized' in a network of relations that lacks central coordination. The network system may then be able to propel itself in an evolutionary mode. The reduction of the uncertainty is a result of the bi-lateral relations. The network system contains more uncertainty-reducing structure than is visible for the interacting agents at their interfaces. The negative entropy can be considered as a flux constrained by the existing relations.

5. Results

In order to show the usefulness of the indicator I will now apply it to relatively simple data like search results with the terms 'university,' 'industry,' 'government,' and their combinations with Boolean AND operators in various databases. The data collection is backgrounded in favour of the data analysis and the methodology. The theoretical question behind the searches is how the relations among these terms reveals a triple helix dynamics operating in the knowledge infrastructure (or not). At which level can a self-propelling dynamic of network relations be observed and to which extent? I first turn to the Internet and then to the *Science Citation Index* for measuring these relations at national and international levels.

5.1 Internet data

University-industry-government relations can be measured at the Internet, for example, in terms of the occurrences and co-occurrences of the words 'university,' 'industry,' and 'government' (Leydesdorff & Curran, 2000). Using various search engines, Bar-Ilan (2001) showed, among other things, how sensitive the Internet is for the measurement at different moments in time (Rousseau, 1999). However, the Altavista Advanced Search Engine is the sole search engine that enables the analyst to combine the various search options with specific time frames (e.g., years) so that time series of data can easily be generated (Leydesdorff, 2001a).[2] I shall use this information for showing the methodology for data *analysis* here under discussion.

[2] Google offers an API-service that allows for programming searches in this domain, including the Julian calendar date (Sylvan J. Katz, *personal communication*).

5.1.1 Internet data

The search terms 'university,' 'industry,' 'government,' and their combinations with Boolean AND-operators were used for the years 1993-2001. All measurements were performed on 24 March 2002, using the AltaVista Advanced Search Engine. The stability of the Search Engine was controlled during the search time at a minimum of once per hour. The results of these searches are shown in Figure 6.

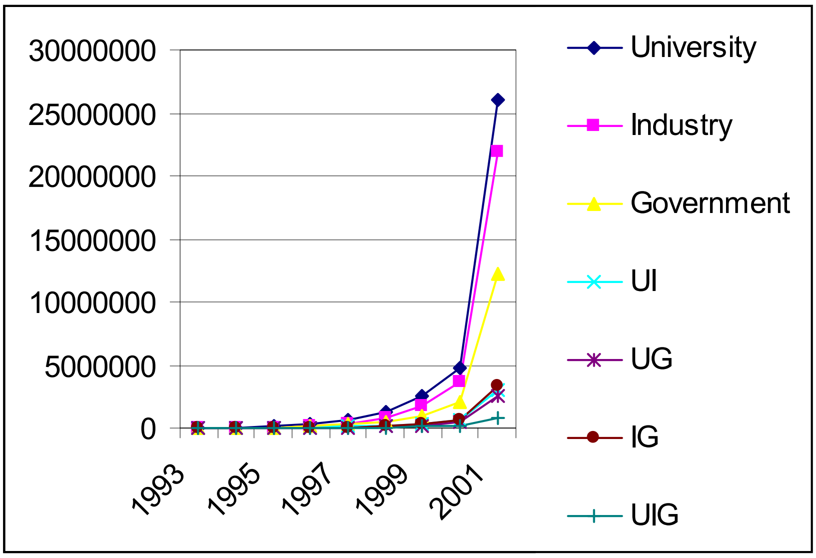


Figure 6

Results of searches using the *AltaVista Advanced Search Engine*

Figure 6 first shows that the Internet continues to expand rapidly. We measured (using AltaVista) more than a billion webpages for 2001 as against approximately 240 million in the year before. In Figure 7 the growth of the AltaVista domain is shown in logarithmic format. Remember that AltaVista only provides a specific representation of the Internet (e.g., Butler, 2000).

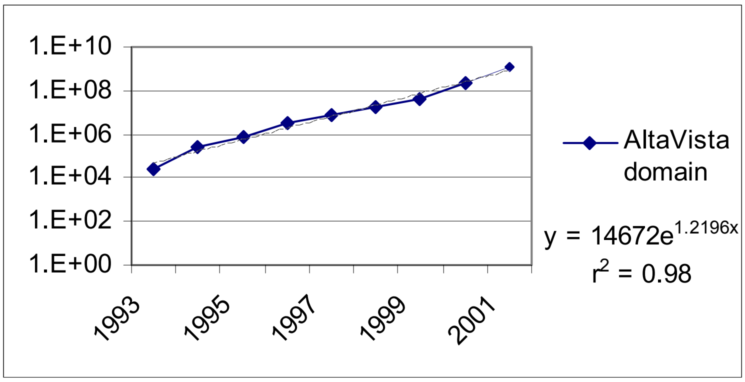


Figure 7

The exponential growth curve of the AltaVista domain

For the computation of the transmission, etc., one has to assume that the search for 'university' provides us with the (margin) total for this search term. The results of the searches 'university AND industry', etc., have then to be substracted from the total number of hits in order to find the relevant number for single occurrences of the word 'university'. This substraction assumes logical consistency in the search engine, but this is only statistically true. For the purposes of this study the relatively small error terms in data gathering can be neglected. As noted, the focus is here on the data analysis and not on the techniques for retrieval.

When the data is organized in a three dimensional array as explained above, the transmission in three dimensions (T(uig)) can straightforwardly be calculated for each year. This leads to Figure 8.

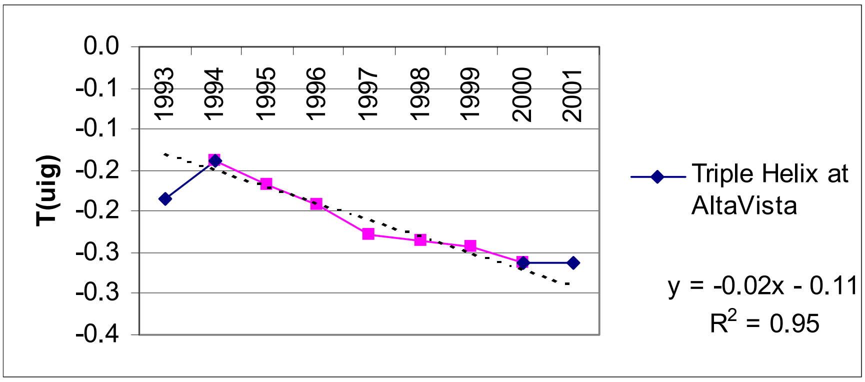


Figure 8

Mutual information in three dimensions ('university,' 'industry,' 'government') as measured using the AltaVista Advanced Search Engine (March 24, 2002).

Figure 8 shows that the values for T(uig) are always negative, but the curve decreases linearly during the period 1995-2000. This period witnessed the booming and the potential self-organization of the so-called new economy. The decrease of the value of the transmission in three dimensions is steady during this period (r^2 = 0.95). Perhaps the flattening of the curve in recent years illustrates that the process of endogenous expansion of the Internet has been interrupted temporarily as the e-business has gone into a recession. Note that this flattening is not noticeable upon visual inspection of the growth data in Figures 6 and 7.

5.1.2 Testing for Systemness

What does the effect of increasingly negative values for T(uig) teach us when compared to the descriptive statistics? Does it indicate the self-organization of a virtual dimension in the overlay of relations generated by the co-occurrences? Can this, indeed, be considered as an indication of increasing self-organization of the system of relations? Are the underlying data in each of the helices also reorganized by the emerging dynamics at the overlay level?

In another context, I developed a test for emerging systemness in data sets against the alternative of historical growth along the time axis (Leydesdorff, 1995). If the overlay in the Triple Helix model exhibits systemness, the carrying institutions continue to develop historically, but the overlay system would then provide another selection environment for them at the global level and in a (historically changing) present. Negative entropy indicates that the overlay system provides the carrying systems with information relevant to reduce the uncertainty.

In the case of emerging systemness, one can expect the set increasingly to contain the Markov property. The Markov property states that the current state of the system is the best prediction of its next stage. If systemness is not achieved, however, the normalized sum of the longitudinal predictions for the various elements provides us with the best prediction for a next state. The two hypotheses can be tested against each other for predicting next year's data. When the predicted values can then be observed, the quality of the two predictions can be evaluated (e.g., Leydesdorff & Oomes, 1999; Riba-Vilanova & Leydesdorff, 2001).

This test is applied using the time series data 1993-2000 for the prediction of 2001 data. Comparison with the observed data for 2001 lead to the following results:

prediction of the value in 2001	7 categories (U, I, G, UI, UG, IG, UIG)	four categories (UI, UG, IG, UIG)	three categories (UI, UG, IG)
on the basis of the univariate time series (1993-2000)	2.06	5.93	5.06
on the basis of the previous year (2000) (Markov property)	2.83	5.54	4.15
hypothesis of systemness	- 0.77 (rejected)	0.39	0.91

Table 1

Testing the hypothesis of systemness in the Triple Helix overlay of University-Industry-Government Relations. (All values are in millibits of information.)

The results show that the prediction of the 2001 data on the basis of the same data for the previous year (Markov property assumed) is inferior to the prediction on the basis of the time series of the various categories in the case of considering the whole system of seven search categories (left column of Table 1). Thus, the hypothesis that the representation would develop as a system is rejected.

When the analysis is limited to the three bi-lateral relations (right column of Table 1), the hypothesis of systemness in the data is corroborated. The quality of this latter prediction is worsened by including the trilateral relations (middle column). Similar results were obtained when using the prediction of the data for the year 2000 on the basis of the time-series 1993-1999, but the results were then even more pronounced.[3]

In summary, these results suggest that the system of representations of university-industry-government relations at the Internet is developing as a set of bilateral relations that contains a negative expected information value and in this sense self-organizes the complexity in the data using a virtual overlay of network relations. This development, however, has slowed down recently.

3

prediction of the value in 2000	7 categories (U, I, G, UI, UG, IG, UIG)	four categories (UI, UG, IG, UIG)	three categories (UI, UG, IG)
on the basis of the univariate time series (1993-1999)	1.25	3.14	3.36
on the basis of the previous year (1999) (Markov property)	2.34	0.27	0.30
hypothesis of systemness	- 0.89 (rejected)	2.87	3.06

Table 1a
Testing the hypothesis of systemness in the Triple Helix overlay of University-Industry-Government Relations for the year 2000. (All values are provided in millibits of information.)

5.2 The *Science Citation Index* (2000)

In a next test of the method, I used the 1,432,401 corporate addresses on the CD-Rom version of the *Science Citation Index 2000*. These addresses point to 725,354 records contained in this database on a total of 778,446 items. Only 3.7 % of these records contain no address information.[4] Our research focuses on the international coauthorship relations in this data, but we will report on that project elsewhere (Wagner & Leydesdorff, in preparation). Here, I focus on University-Industry-Government relations in this data set.

An attempt was made to organize all the addresses automatically in terms of their attribution to university-industry-government relations. This was done by a routine that first attributed a university label to addresses that contained the abbreviations 'UNIV' or 'COLL.' Once an attribution was made, the record was set aside before further attributions were made. The remaining addresses were subsequently labeled as 'industrial' if they contained one of the following identifiers 'CORP', 'INC', 'LTD', 'SA' or 'AG'. Thereafter, the file was scanned for the identifiers of public research institutions using 'NATL', 'NACL', 'NAZL', 'GOVT', 'MINIST', 'ACAD', 'INST', 'NIH', 'HOSP', 'HOP ', 'EUROPEAN', 'US', 'CNRS', 'CERN', 'INRA', and 'BUNDES' as identifiers.

[4] The total number of authors in this database is 3,060,436. Thus, on average each record relates to four authors, but at two addresses.

This procedure enabled us to identify 1,239,848, that is 86.6% of the total number of address records, in terms of their origin as ‘university,’ ‘industry,’ or ‘government.’ The distribution is exhibited in Table 2:

	Number of records	*Percentage*
‘University’	878,427	61.3
‘Inudstry’	46,952	3.3
‘Government’	314,469	22.0
– (not identified)	192,553	13.4
Total	1,432,401	100

Table 2

Number of records in the *Science Citation Index 2000* that could be attributed with a Triple Helix label using a routine

The thus identified addresses refer to 676,511 (93.3%) of the 725,354 records in the database that contain address information. Furthermore, the address information also contains the country names. For the purpose of this study, records containing an address in England, Scotland, Wales or Northern Ireland were labeled ‘UK,’ and analogously a dataset for the EU was composed containing all records with addresses in the member states. The label ‘Scandinavia’ was added to all records containing an address in Norway, Sweden, Denmark, and Finland. A subset of the 120,086 internationally co-authored papers could also be defined.

For all these subsets a three-dimensional transmission of Triple Helix relations can be calculated. The results of this calculation are shown in Table 3.

	number	% ti	T(uig) in mbits	UI	UG	IG	UIG	Univers	Industry	Govern
all	676511	93.3	-77.0	16270	108919	4359	5201	543123	41242	232096
USA	232571	92.5	-74.4	7200	37834	1782	2666	200149	18154	66416
EU	257376	93.0	-50.1	4455	52112	1485	2028	206747	11192	101545
JAPAN	67715	97.9	-92.1	4147	12492	954	1311	56534	9732	21664
UK	68404	93.1	-63.1	1719	13098	394	690	54823	3970	26202
GERMANY	61017	94.7	-43.4	1028	14003	407	664	51283	2799	23701
FRANCE	41112	90.3	-52.1	439	11593	452	530	26133	1928	26595
SCAND	30939	95.8	-31.6	490	8477	162	371	26542	1263	13005
ITALY	28958	89.9	-29.4	362	7133	87	262	25633	905	10526
NETHERL	18357	95.3	-25.4	372	4482	106	259	16379	863	6593
RUSSIA	22767	98.6	-24.2	76	6315	162	138	11507	478	17611
INDIA	10916	89.2	-78.1	97	1813	61	55	6099	407	6492
BRAZIL	9120	91.0	-22.4	137	1727	32	52	7968	267	2885
internat. coauthored	120086	98.9	-21.9	4550	47054	1349	2545	107569	9422	61138

Table 3

University-industry-government relations for various countries and regions using ISI's *Science Citation Index 2000.*

Table 3 shows a very different pattern for the Triple Helix developments in various world regions. The triple helix overlay operates within the U.S.A. and the Asian-Pacific countries at a much higher level of self-organization than in Europe. Within the European Union, one can observe a scale with the UK at the leading end, but the smaller units (e.g., The Netherlands) at much lower levels. Russia and Brazil are even less integrated in this respect, but India exhibits the Asian-Pacific pattern ($T < -0.70$).

In terms of the three-dimensional transmission, Japan is by far more sub-integrated in a Triple Helix mode than other countries included in this analysis. This can already be seen on visual inspection of the numbers. For example, the number of papers with both university and industry addresses in Japan is 4147 against 4455 for the whole EU. This is 7.3% and 2.2% of all university papers in these two subsets, respectively.

In France the ratio of university papers coauthored with industry is only 1.7%. In this case, the relation between industry and government is even stronger than the one between the university sector and industry. The relations between university research and public sector research are strong everywhere, but in France, Russia, and India public sector research is larger than university research in terms of scientific output. Note that more than 39% of the internationally coauthored papers contain an address of both a university and a government agency.

Furthermore there seems to be a size effect of the T(uig) among nations, but this effect is not statistically significant. The main distinction is visible as a pattern of collaboration that is culturally specific. The academic system on the continent in Europe seems much more traditional in its patterns of collaboration than in the U.S.A. or Japan. University-Government relations are more established in these

European nations than University-Industry relations. Russia and France are the most extreme cases in this respect. The papers based on international collaborations exhibit the least integration in the Triple Helix relations using this indicator.

Let me add a caveat on reading these results. The results refer only to the representation in the *Science Citation Index* and the above classification into sectors was statistical. Industry is weakly represented in this data. Collaborations with industry may often not lead to this type of scientific publications. The purpose of this study, however, was to show the three-dimensional transmission as a methodology for data analysis. Data collection may require more care. Yet, insofar as university-industry-government relations are operationalized as networks, the data can always be written as relative frequency distributions. The indicator of the three-dimensional transmission can then be applied for the comparison of the state of the Triple Helix configurations.

5.3 Two further tests

The above results suggest that the Triple Helix is operating strongly as an overlay in the system of global representations, but not similarly at the national level in all the advanced countries. On the contrary, cultural patterns seem to intervene. I shall now proceed by adding two further types of analysis, notably the representation of national systems at the level of an international database and the representation of an international system at the level of a national database. These two tests enable me to specify the dynamics of globalization and triple helix relations in more detail.

5.3.1 National subdomains and languages at the Internet

The Internet is a global system, but it can be searched specifically for national domains using the domain name (e.g, '.br' for Brazil) and/or the national language (Portuguese in this case). In Leydesdorff & Curran (2000) we explored these various dimensions. In this study, three national domains with their respective languages will be used: Brazil (.br) with Portuguese, Germany (.de) with German, and the Netherlands (.nl) with Dutch. Among the many possibilities, Brazil and the Netherlands were selected for the comparison with our previous analysis. Germany was added as a third case with a larger economy because Brazil and the Netherlands also exhibited some similarities in our previous analysis.

After consultation of a number of native speakers, the following search terms were selected:

	University	*Industry*	*Government*
Portuguese	Universidade	Indústria	Governo
German	Universit*	Industr*	Bundes*
Dutch	Universit*	Industr*	Overheid

Table 4

Search terms for triple helix relations in different national languages

The similarity with the English search terms in German and Dutch makes it possible to include the terms more globally, possibly disadvantaging Portuguese. However, the results exhibited in Figure 9 are very clear and robust: the global development at the Internet prevails over national differences as the Internet further developed during the 1990s.

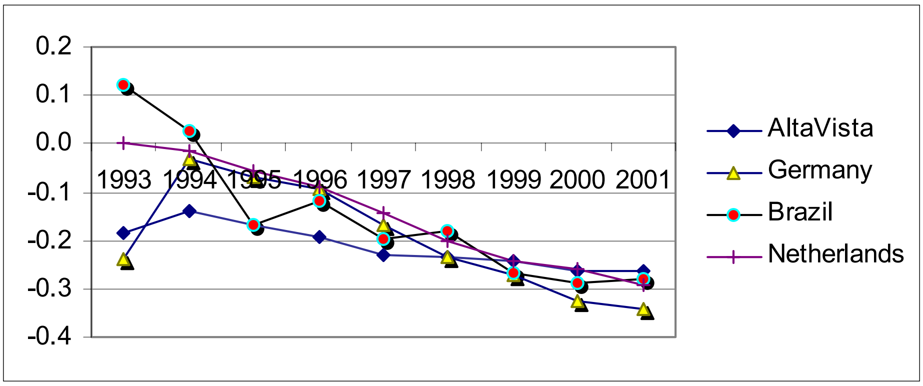


Figure 9

The three-dimensional transmission between 'university,' 'industry,' and 'government' in various national systems and languages during the period 1993-2001

Although initially (1993-1995), these 'national' representations of Triple Helix configurations were differently integrated and differentiated at the Internet, the global dynamics harmonized these systems into a similar pattern of representation during the years thereafter. The self-organization of Triple Helix relations at the Internet has prevailed over national differences in terms of domains and languages.

5.3.2 US Patent data

The database of the U.S. Patent and Trademark Office (USPTO) provides us with a nationally organized database which can be used as a window on international developments of patents because it integrates patent applications from around the world at the level of the American market (Narin & Olivastro, 1988; Granstrand, 1999).

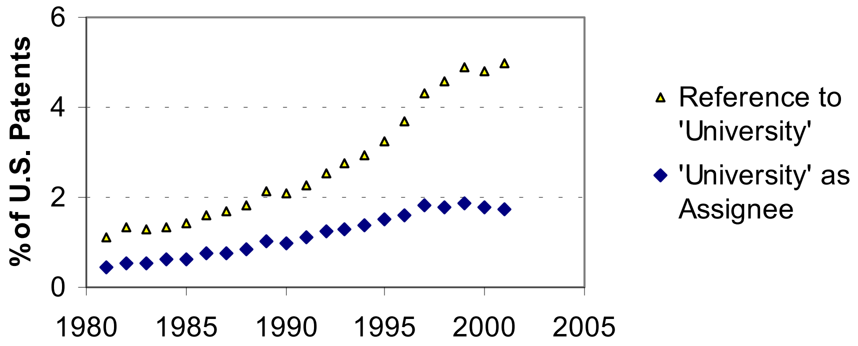
'University,' 'industry,' and 'government,' and the various combinations with Boolean 'AND' operators can also be used as keywords in this database. As in the case of the Internet, I searched the patent database for the number of occurrences of these terms in the file on a year-to-year basis. For reasons of comparison with the Internet analysis above, the time-series in Table 5 was limited to the period 1993-2001.

Year	University	Industry	Government	UI	UG	IG	UIG	Total number of patents
1993	3063	9716	2619	401	588	334	63	110540
1994	3359	10568	2855	479	684	390	89	114564
1995	3710	10800	2828	529	771	410	93	114864
1996	4552	12147	3149	703	963	488	114	122953
1997	5406	12699	3604	814	1199	583	168	125884
1998	7623	17068	4708	1254	1658	807	266	166801
1999	8326	18553	4856	1352	1735	844	235	170265
2000	8488	19368	4831	1399	1776	865	267	176350
2001	9190	20812	5136	1591	1868	996	296	184172

Table 5

The number of hits for the search terms 'university,' 'industry,' and 'government' and their combinations in the database of the U.S. Patent and Trade Office.

Note that the number of patents recalled with the search term 'university' has grown steadily over the period, but this growth has declined during the later years. This breach in the trend can be made even more visible by searching for the term 'university' among the patent assignees as is shown in Figure 10 for the whole period since the introduction of patent rights for universities by the Bayh-Dole Act



of 1980.

Figure 10

Percentage of U.S. Patents (i) with a reference to the word 'university' and (ii) a 'university' among the assignees

During the 1980s and the early 1990s the value of the three-dimensional transmission among the dimensions 'university,' 'industry,' and 'government' has remained stable.[5] But during the 1990s this value has began to rise indicating a tendency towards a more centrally integrated system (Figure 11).

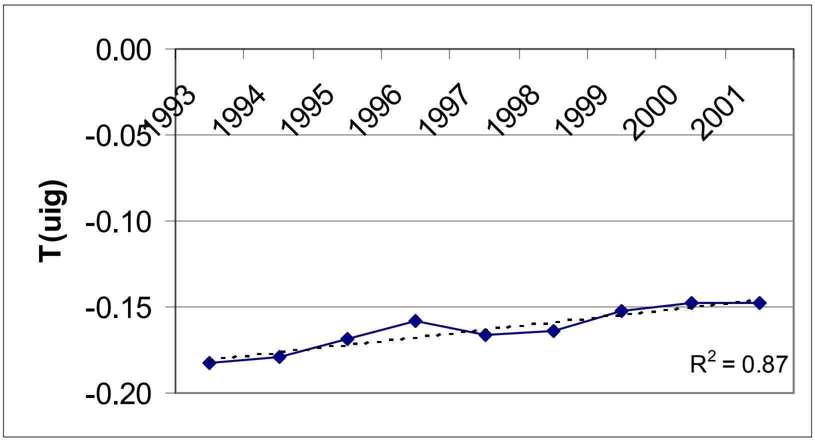


Figure 11

The mutual information among 'university,' 'industry,' and 'government' relations in the database of the U.S. Patent and Trade Office

With hindsight, the Bayh-Dole Act of 1980 can be considered as having provided the patent system with one more degree of freedom, that is, by allowing universities increasingly to become players in this institutional field. (The Bayh-Dole Act granted universities the right to patent results from federally funded research.) The patent system, however, has remained a highly institutionalized system of legal control and therefore under the pressure of integration. New players can be expected to be enrolled within this system in due time.

6. Conclusions

Triple Helix networks can be measured as network data. These representations by no means have to be restricted to the terms 'university,' 'industry,' and 'government' as

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[5] During the period 1976-1992, T_{UIG} had remained equal to -0.190 ± 0.008.

search terms in a database. However, I used the relatively straightforward results from these searches in order to show how the algorithmic indicator of the mutual information enables us to distinguish among observable Triple Helix arrangements.

For example, one can measure the discourse at the university level in terms of word occurrences and then wish to compare the results in this discourse with the discourse in the relevant industry and government systems. Matrices (or higher-order arrays) of words used at different instances or variables measured in the various contexts can first be compared in terms of their overlap. The 'mutual information' can also be considered as the covariation. At each side, one expects remaining variation, for example, terms which are used (or have meaning) within industry, but not in academia.

If the data representation is sufficiently complex, that is, containing three dimensions, the representation can be evaluated using the three-dimensional transmission. In this study, I chose for the use of scientometric and webometric representations in order to show how triple helix relations work differently at the national and at the global level. The theoretical assumption was that university-industry-government relations exhibit the knowledge *infrastructure* of the knowledge-based *dynamics* under study.

The knowledge development can be studied using the three-dimensional transmission because entropy can be considered as a measure of the flux. Whether the overlay of the relations had also become systemic and how it then operates, for example, in terms of bilateral and trilateral relations could further be analyzed using information theoretical measures (Leydesdorff, 2001b).

At the global level, the system of representations at the Internet has gone through a rapid phase of expansion and it exhibited a negative transmission in three dimensions that is further deepening. The self-organization of the probabilistic entropy in this representation, however, was based only on the system of bi-lateral relations. The representations at the national level within this global system followed the trend and this confirms the assumption of a global development.

Using the ISI-database different patterns of integration became visible among cultural regions of the globe. Industry seems much less integrated into the academic system in Europe than in the U.S.A. and in Asia, in terms of their participation in academic publications. By using the perspective of the nationally integrated U.S. patent system, I could then show that a nationally integrating system like the U.S. Patent Office exerts feedback on an otherwise expanding domain. The expansion of the patent system is moderated.

Finally, I indicated how the systemness of the overlay can be evaluated in comparison to the systemness of the representations of the composing units (e.g., university, industry, and government). In the case of the Internet, the bi-lateral relations between the search terms carried the systemness. The self-organization of the knowledge-based economy can thus be considered as a Triple Helix development at the global level, while nations differ in terms of how they participate in these developments.

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