Organizational Capability for Responding to Technology Globalisation

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Abstract

Quantitative analysis of economic or scientific research activities often involve comparison of performance across organizations such as firms in case of economics (in Econometrics) or institutions in case of research activity (in Scientometrics). The dynamic processes inside an organization generate over time learning capability to respond to and incorporate innovation and change thereby impacting its output over time. Organizational processes however are usually not taken account of in econometrics or scientometrics analysis of performance; these are examined in management studies. The paper shows that impact of organizational process can be incorporated in econometrics and scientometrics studies also by applying relatively new techniques of permutation entropy and network analysis on time series data. As an illustrative example, dynamic processes embedded in performance of Indian Universities that engage in scientific research are discerned using time series data of their respective output of published papers. Results are interpreted in terms of 'learning capabilities' of organizations. Some institutions are seen to have acquired higher learning capability than others and are thus better prepared to incorporate new ideas and adjust to changing national and international research environment. Generic similarities between our results and those of management studies are pointed out.

Introduction

Globalisation has brought in a major change in the working of firms. "Responsibilities that were earlier considered as core functions of the company have shifted to outsiders via outsourcing, joint ventures and other sorts of alliances that involve a loosening of direct control over vital inputs" [1]. In addition to traditional trade flows, the globalization of production and markets has greatly enhanced the complexity of the international division of labour and of alliances.

All economic activity and research and development work require institutional support. The importance of institutional support to firm level performance was first highlighted in studies of Japanese firms. It was noted the Japanese firms derived their competiveness from the unique and effective management of institutional support to employment, subcontracting and financial alliances [2]. In the context of research, development and innovation, concept of national innovation system and need for having enabling 'eco-

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system' also point to the importance of institutional support and processes through which these are made available.

Globalisation of production and research coupled with increased competitiveness has introduced enhanced premium on studies of institutional processes and on learning capabilities of organisations to face changing economic environment [3] . Firms are required to adjust and evolve effective institutional support processes amongst partners coming from vastly different behavioural environment[4]. Success of technology alliances between firms with different institutional behavioural environment also require the firms in the alliance network to learn from working together and 'become different in more ways than existing research would have us believe' [5].

Recognising the premium placed by globalisation on learning behaviour of economic and research organisations, the paper explores a quantitative method of indexing the learning capability of organisations. Although microanalysis of behaviour of organisation is formidably complex, new modes of analysis such as information economics, game theory, agency theory, and population ecology have emerged [6].

We have used yet another mode of analysis known as permutation entropy deployed in characterisation of a variety of complex systems encountered in nature. This method is described in section 2. To illustrate the application of the method in characterising the learning behaviour of organisation, we give an example from research activity taking universities as a research organisation.

Admittedly the conclusions drawn and discussed in the last section are only indicative in nature. Applying the method presented in the paper to index learning capabilities of firms can draw more meaningful conclusions.

2. Materials and Methods:

In this work, we analyse the time series data of research publications of various central and state universities using the idea of permutation entropy as it is able to quantify the complexity of the various underlying processes involved. Publication Data for the period 1990-2012 for 12 Indian Universities e.g., Aligarh Muslim University, Delhi University, Banaras Hindu University, Allahabad University, Hyderabad University, Pondicherry University, Visva Bharti University, Jamia Milia University, Jawahar Lal Nehru university , Tripura University, Manipur University and North Eastern Hill University, have been considered in the present analysis.

In fact most of the method available for studies related to complexity measure are usually based on a system construct or model involving several constituents which are interacting with each other based on certain rules given a priori based on some theory . However , time series data of a variable embeds the information regarding processes involved at various stages. It is in fact the results of interaction of such processes that leads to the complexity of a system. In the following , we provide some basic idea of computing the permutation entropy that is used as a tool to measure the complexity of research publication of various universities mentioned above.

We assume the publication activity to be discrete i.e., yearly number of research papers is a positive integer. Denoting the number of research papers published as a discrete variable $X(t)$, the probability p of $X(t)$ can be mathematically expressed as:

$$p = \{p_i : i = 1,2, \ldots\ldots, M\} , \qquad (1)$$

where M is the degrees of freedom.

The Shannon's entropy, S, therefore is given by the following equation:

$$S[P] = -\sum_{i=1}^{M} p_i \, ln(p_i). \qquad (2)$$

If $S[P] = S_{min} = 0$, then the system is deterministic, as it is possible to predict outcome i of an event with a probability $p_i = 1$. Further, as in the case of a perfect dice the probability, p_i, of observing either 1,2,3,4,5 or 6 is $1/_6$. Here, the sample space size $M = 6$, and since the outcome of an event of throwing a perfect dice is independent of any other event, the probability is uniformly distributed over all possible outcome i.e., $p_i = 1/_6$, $\forall\, i = 1,2,3, \ldots ,6$. Therefore , in general, if the probability function is uniformly distributed over various degree of freedom i.e., ($p_i = \{\frac{1}{M}$, $\forall i = 1, \ldots , M\}$), then the maximum Shanon's entropy of the system $S[p] = S_{max} = ln\, M$. In such a case only minimal information is available for the system. Therefore the complexity of a system measured in terms of Shanon's entropy S lies in the range $[0, \ln M]$. In the foregoing description one may note that the knowledge of the probability of a state and hence the processes involved, is assumed a priori and this may not be true always. Recently, the ideas of symbolic dynamics have been extensively used in the analysis of non-liner complex systems encountered in many physical, biological and social systems [7]. Symbolic dynamics links raw time series measurements to symbols or patterns that the output generating dynamics embeds over time in the system.

We therefore adopt symbolic dynamics to discern various patterns giving rise to a complex system in the form of a time series of research article published in a journal. Since the existence of a pattern is a result of combination of several factor responsible for its occurrence but at the same time each pattern is independent of the other, unlike the case of Shanon's entropy, we need not know a priori any probability distribution function of the output processes a priori. Thus the symbolic dynamics used to identify different possible pattern of a time series is able to capture hitherto neglected possible feature of 'self learning' capability expected to get embedded in a system or organization involving human intelligence. The 'learning' from out put(s) of an event or events may alter the probability of occurrence of next and subsequent events in such a way that over time, the number of probable states or patterns get discarded and thus evolving the dynamical behaviour of the system to a higher 'deterministic' level.

Bandt and Pompe [8] have provided a method of deciphering symbols or patterns in terms of a 'complexity index' by estimating 'permutation entropy' (P_E) from time series. Unlike estimation of Shannon Entropy the method does not require assumptions, models and theories and uses only information on temporal relationship between neighbouring values in a time series data [9]. Further, the parametric behaviour of P_E is quite analogous to Lyapunov exponents and is therefore structurally robust to noise in a real world time series.

Consider the general time series

$$X = \{x_t : t = 1,2 \ldots., N\}. \qquad (3)$$

At each time $t = \tau$, a vector composed of the n-th subsequent values is constructed:

$$\tau \vdash \left(x_\tau, x_{\tau+1}, \ldots., x_{\tau+(n-2)}, x_{\tau+(n-1)}\right), \qquad (4)$$

where n termed as dimension corresponds to quantum of information contained in each vector. An ordinal pattern may be defined as the permutation

$$\pi = (r_0 r_1 \ldots . r_{n-1})$$

of $(01 \ldots \ldots [\mathrm{n}-1])$ and is associated to this vector, such that

$$x_{\tau+r_0} \leq x_{\tau+r_1} \leq \cdots \leq x_{\tau+r_{n-2}} \leq x_{\tau+r_{n-1}} \qquad (5)$$

In other words one needs to sort values of each vector in an ascending order, and create a permutation pattern π with the offset of the permuted values. For instance, if $x = (2, 6, 9, 10, 7, 10, 3)$, then it is readily observed that for $\mathrm{n} = 3$, 2 patterns (0,1,2) correspond to $x_t < x_{t+1} < x_{t+2}$; 2 patterns (2,0,1) correspond to $x_{t+2} < x_t < x_{t+1}$ and 1 pattern (1,0,2) corresponds to $x_{t+1} < x_t < x_{t+2}$ results in permutation entropy $P_E = 1.5219$. Therefore for the time series $\{x_t\}_{t=1 \ldots N}$, all permutation n! of π are considered to define the relative frequency

$$p(\pi) = \frac{\#\{t \mid 0 \leq t \leq N-n, (x_{t+1}, \ldots, x_{t+n}) \; has \; type \; \pi\}}{N-n+1} \qquad (6)$$

The permutation entropy P_E is defined as:

$$P_E = -\sum p(\pi) \ln p(\pi) \qquad (7)$$

where for a given order n, the sum is taken over all $n!$ permutations π.

One can then infer that during the same period of operation, systems with lower P_E values would have attained higher determinisms or certainty in giving an output compared to those with higher P_E values.

To apply this approach to the systems that publish Journals, we estimate P_E from time series data of number papers published in journals per year from different universities. The calculated complexity indices would then allow a comparative study of nature of complexity or level of 'determinism' inherent in the dynamics of journal publishing systems of different universities.

3.Results and discussions:

The plot of the time series of research publication of 12 universities is shown in Fig.1. Complex nature of publication processes are quite visible and further a closer look reveals that the pattern of publication output at different times is different for different universities. The use of symbolic dynamics enables one to obtain various exclusive pattern associated with a time series of research publication brought out by universities for the period 1990-2012 and further application of eq.(7) results in the complexity measure of research publication as shown in Table:1. It is readily seen that the established universities have lower values of the permutation entropy P_E and hence complexity compare to newly established universities. This is primarily due to their higher learning capabilities acquired a period of time.

It is further noted that Aligarh Muslim University has lowest complexity value followed by Delhi University. Further a large number of new universities have comparable complexity values. It is apparent that possibly the support structures in these universities would improve over time and subsequently may reduce the inter-university differences considerably.

In analogy with the university as a production organisation giving research paper as out put, one can use the technique presented in the paper to characterise the learning capabilities of embedded in firms by analysing their production time series data. The measure of complexity of time series data therefore provides a quantitative tool for indexing the learning capabilities of firms and organisations engaged in economic and knowledge generating activities.

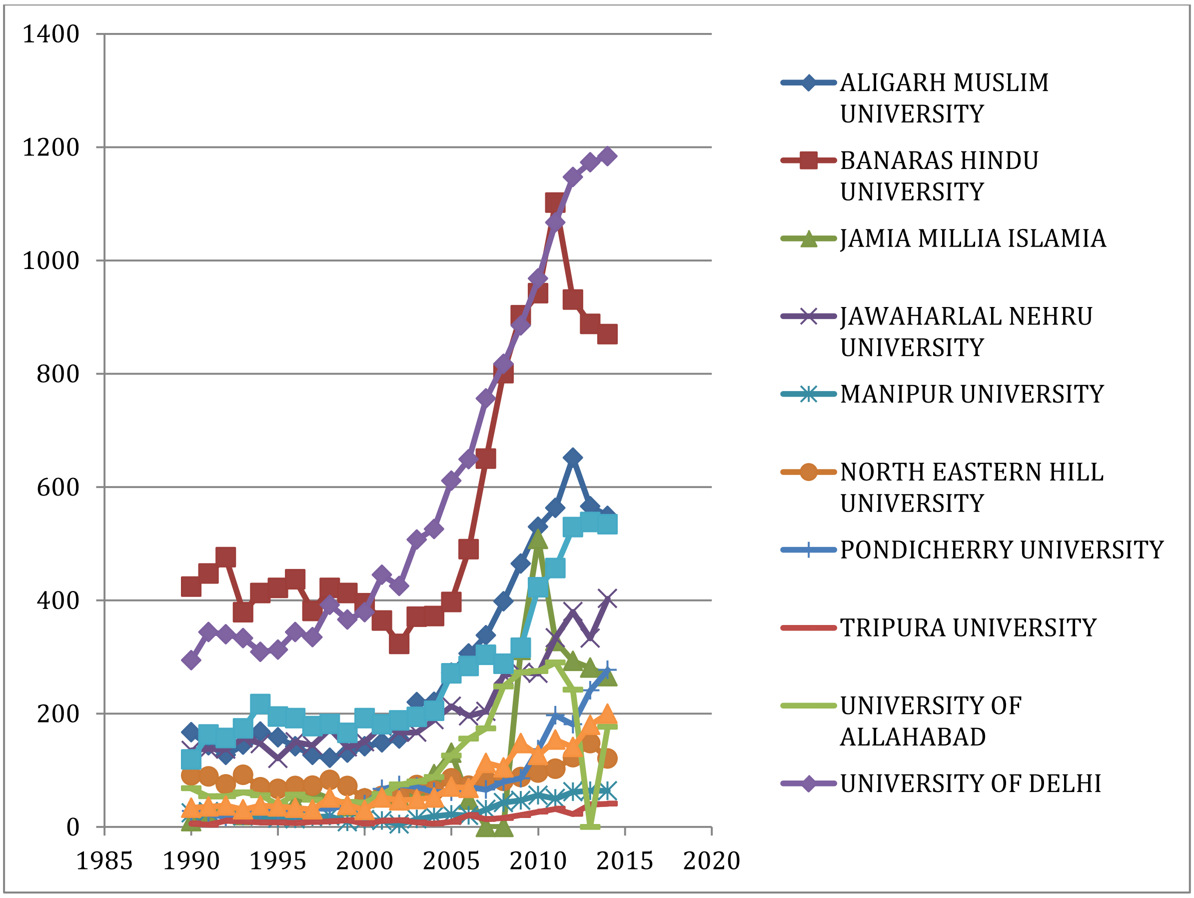

Fig.1

Table:1
Permutation Entropy of Publication Data for the period 1990-2012 for 12 Indian Universities

S.No	University	Permutation Entropy
1	Aligarh Muslim University	1.5274
2	Delhi University	1.8233
3	Banaras Hindu University	2.0706
4	Allahabad University	2.1619
5	Hyderabad University	2.1938
6	Pondicherry University	2.2097
7	Visva Bharti University	2.2602
8	Jamia Milia University	2.3108
9	Jawahar Lal Nehru Univ.	2.3764
10	Tripura University	2.4038
11	Manipur University	2.4251
12	North Eastern Hill Univ.	2.4962

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