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Topology of foreign exchange markets using hierarchical structure methods

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Abstract

This paper uses two physics derived hierarchical techniques, a minimal spanning tree and an ultrametric hierarchical tree, to extract a topological influence map for major currencies from the ultrametric distance matrix for 1995–2001. We find that these two techniques generate a defined and robust scale free network with meaningful taxonomy. The topology is shown to be robust with respect to method, to time horizon and is stable during market crises. This topology, appropriately used, gives a useful guide to determining the underlying economic or regional causal relationships for individual currencies and to understanding the dynamics of exchange rate price determination as part of a complex network.
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1. Introduction

Hierarchical structure methods are used in finance to ascertain the structure of asset price influences within a market. These methods use the synchronous correlation coefficient matrix of daily difference of log prices to quantify the pricing distance between assets in terms of the inherent hierarchical structure. This structure will give some indication of the taxonomy of an asset's portfolio, and can be used to generate an asset market's hierarchy.

Two techniques will be used in this paper. The first technique is the creation of a *minimal spanning tree* (MST), which is a graph of a set of n elements of the arrangement of the nodes in an *ultrametric space*. MST has been shown to provide sound results for financial assets with the resultant taxonomy displaying meaningful clusters [1–4]. MST also helps to overcome the empirical problem of noise in a historical correlation matrix [5,6].

The second technique is the creation of an *ultrametric hierarchical tree* structure [6,7]. This technique gives a determination of the hierarchical structure of a network and is particularly useful for determining if hubs exist.

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The structure of asset price movements is extracted by use of a synchronous correlation coefficient matrix, A_{ij}, of daily difference of log prices. This matrix is transformed [8] by the equation below to get the ultrametric pricing distance between currencies. This metric is preferred to correlation as it fulfils the three axioms of a metric distance [1],

$$d(i,j) = \sqrt{2(1 - A_{ij})}.$$

The choice of clustering procedure is vital as it has more effect on the quality of clustering than does the choice of distance metric [9]. MST analysis uses the single-linkage clustering method which builds up clusters by starting with distinct objects and linking them based on similarity. The major issue with this method is that while it is robust for strongly clustered networks, it has a tendency to link poorly clustered groups into chains by successively joining them to their nearest neighbours [10]. These chains are non-robust to data variation, and thus MST is less robust for larger distances. The information obtained should thus be used with care and be combined with other techniques if possible. This paper will focus on the extraction of price influences rather than on determinants of market activity.

2. The data

Forty-four currencies (Table 1) were chosen because they were generally free floating, covered the data period (23/10/95–31/12/01) and had either market dominance or represented a region. The Mexican peso and Russian rouble were used in their format prior to currency reforms, which removed three zeros. Data were sourced from Oanda.com at Olsen and Associates. The end date coincides with the introduction of the Euro. The exchange rates were daily average inter-bank ask rates as determined in Zurich. This should give some idea of how international currencies interact, how the currency nodes are clustered, and the pattern behind price influences. This is a small sample compared to stock market studies, which will limit possible topologies.

Table 1
Countries selected for exchange data

Currency	Code	Currency	Code
Algerian Dinar	DZD	Italian Lira	ITL
Australian Dollar	AUD	Japanese Yen	JPY
Bangladeshi Taka	BDT	Jamaican Dollar	JMD
Belgium Franc	BEF	Kazakhstan Tenge	KZT
Bolivian Boliviano	BOB	Kenyan Shilling	KES
British Pound	GBP	Malaysian Ringgit	MYR
Brazilian Real	BRL	Mexican Peso	MXN
Canadian Dollar	CAD	New Zealand Dollar	NZD
Chilean Peso	CLP	Pakistan Rupee	PKR
Colombian Peso	COP	Papua New Guinea Kina	PGK
Czech Koruna	CZK	Philippine Peso	PHP
Danish Krone	DKK	Polish Zloty	PLN
Dutch Guilder	NLG	Qatar Rial	QAR
Eqyptian Pound	EGP	Russian Rouble	RUB
Fiji Dollar	FJD	Saudi Arabian Riyal	SAR
Finnish Markka	FIM	Singapore Dollar	SGD
French France	FRF	South Korean Won	SKW
Ghanaian Cedi	GHC	South African Rand	ZAR
German Deutsche Mark	DEM	Swedish Krona	SEK
Indian Rupee	INR	Swiss Franc	CHF
Indonesian Rupiah	IDR	Taiwan Dollar	TWD
Iranian Rial	IRR	Thai Baht	THB

Currency and international quotation code (23/10/1995–31/12/2001).

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