

Information and Arbitrage: Applications of Quantum Groups in Mathematical Finance

Paul McCloud

Department of Mathematics, University College London, UK

The relationship between expectation and price is commonly established with two principles: *no-arbitrage*, which asserts that both maps are positive; and *equivalence*, which asserts that the maps share the same null events. Constructed from the Arrow-Debreu securities, classical and quantum models of economics are then distinguished by their respective use of classical and quantum logic, following the program of von Neumann.

In this essay, the operations and axioms of quantum groups are discovered in the minimal preconditions of stochastic and functional calculus, making this the natural domain for the axiomatic development of mathematical finance. Quantum economics emerges from the twin pillars of the Gelfand-Naimark-Segal construction, implementing the principle of no-arbitrage, and the Radon-Nikodym theorem, implementing the principle of equivalence.

Exploiting quantum group duality, a holographic principle that exchanges the roles of state and observable creates two distinct economic models from the same set of elementary valuations. Advocating on the grounds that this contains and extends classical economics, noncommutativity is presented as a modelling resource, with novel applications in the pricing of options and other derivative securities.

1 Introduction

The data associated with a system is presented in this essay as a pair of complementary \ast -algebras, comprising the states and observables that are combined in the investigation of the system. The state space M and the observable space W are

Paul McCloud: p.mccloud@ucl.ac.uk

paired by a bilinear map:

$$\bullet : M \times W \rightarrow \mathbb{C}$$

that sends the state $z \in M$ and the observable $a \in W$ to their valuation $z \bullet a \in \mathbb{C}$. With the emphasis on empirical determination, the states and observables are completed as locally convex topological spaces that include all the experiments uniquely identified by their valuations. Using the operations of the \ast -algebras, stochastic and functional calculus can then be developed on the category of empirical systems, hereafter referred to as the *empirical category*.

Contextualising this to mathematical finance, the state represents a market and the observable represents a security; the pairing is then the price of the security in the market. The two-dimensional nature of this data construct is evident in the following example market for interest rate swaps on three consecutive days:

	mkt1	mkt2	mkt3
sw1y	5.118%	5.075%	5.008%
sw2y	4.395%	4.322%	4.248%
sw5y	3.629%	3.563%	3.497%
sw10y	3.449%	3.399%	3.351%
sw20y	3.402%	3.373%	3.335%

The pairing is lookup in this elementary market, as with the sample valuation:

$$\text{mkt3} \bullet \text{sw2y} = 4.248\%$$

where the state is the market mkt3 on the third day and the observable is the swap rate sw2y maturing in two years. The *a priori* structure comprises the basis markets and securities that are available to the market agent, and the *a posteriori* structure is the data that populates the table. Analysis then identifies patterns within the data, reducing its dimensionality and supporting algorithmic trading and risk management.

Quantum Groups Applications

Hussin A.Rothana



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