The Economic Potential of Process Stoichiometries in Incomplete Markets

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May 13, 2014

Abstract

Modern analysis and design of chemical processes involves the integration of financial and plant operations. A key aspect in optimizing process goals is the attainment of economic and thermodynamic feasibility. In previous work, we proposed a process model for the underlying reactions, stoichiometry, mass and energy balances of a complex chemical process by imposing a minimal set of assumptions regarding the uncertain nature of price dynamics in the commodity markets [5]. Employing a framework developed by Shinnar [9, 8], Hildebrandt and Glasser [3, 2, 1] for chemical stoichiometry and thermodynamics we establish a modern stochastic interpretation of the concept of "economic potential" first proposed by Douglas [4].

A process model is formulated using the idea of a "simple process" [3, 2, 1], which combines basic chemical stoichiometry and thermodynamics to determine its feasibility. We then construct an investment portfolio comprised of commodities and risk-free assets to pose an investment problem, which calculates the "fair" price for leasing a unit of capacity of this chemical process. A focal point of this work is to illustrate how to obtain arbitrage-free scenario trees for stochastic commodity prices [6, 7]. Because the underlying assets cannot span the dynamics of this portfolio the market is "incomplete", which results in the existence of a range of prices. A linear programming problem is then solved to obtain the upper and lower bounds to the prices of this process lease or what in quantitative finance is known as the bid-ask price [10]. Tighter bounds are established by introducing second order stochastic dominance – the natural generalization of conditional value at risk – to measure preferences of risk-averse operators.

These markets are characterized for subjecting their participants to some degree of financial risk, which in turn may represent monetary losses. A key point of this study will be to determine efficient ways to hedge this risk and minimize the likelihood of incurring a deficit.

Keywords: Process stoichiometry, valuation, incomplete markets.

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