

# Recovery Theorem with a Multivariate Markov Chain\*

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## Abstract

In this paper, I redefine the prices derived in Ross' Recovery Theorem (Ross, 2015) using a multivariate Markov chain rather than a univariate one. I employ a mixture transition distribution where the proposed states depend on the level of the S&P 500 index and its options' implied volatilities. I include volatility because the transition path between states depends on the propensity of an underlying asset to vary. An asset that is highly volatile is more likely to transition to a far-away state. These higher transition probabilities should lead to higher state prices. The multivariate method improves upon the univariate RT because the latter does not include the volatility inherent in the state transition, which makes its derived prices less precise. The multivariate RT produces forecast results far superior to the univariate RT. Using quarterly forecasts for the 1996-2015 period, the out-of-sample R-square of the RT increases from around 12% to 30%. Moreover, using simulated data, I show that including the implied volatility in the multivariate Markov chain more closely captures the inherent risk in business cycles.

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