

# Variable Annuities in a Lévy-Based Hybrid Model with Surrender Risk

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Variable annuities are unit-linked investment policies providing a postretirement income, which is generated by the returns on a suitably managed financial portfolio. Various guarantees are applied with the aim of providing protection of the policyholders' saving accounts. Variable annuities are popular insurance products in the US, Japan, the UK, and are increasingly present in the other European markets as well. The paper proposes a market consistent valuation framework for variable annuities with guaranteed minimum accumulation benefit, death benefit and surrender benefit features. The setup is based on a hybrid model for the financial market and uses time-inhomogeneous Lévy processes as risk drivers. Further, we allow for dependence between financial and surrender risks. The model leads to explicit analytical formulas for the quantities of interest, and practical and efficient numerical procedures for the evaluation of these formulas. We illustrate the tractability of this approach by means of a detailed sensitivity analysis of the fair value of the variable annuity and its embedded options with respect to the model parameters. The results highlight the role played by the surrender behavior and the importance of its appropriate modelling.