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Mortgage loan portfolio optimization using multi-stage stochastic programming

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Abstract

We consider the dynamics of the Danish mortgage loan system and propose several models to reflect the choices of a mortgagor as well as his attitude towards risk. The models are formulated as multi-stage stochastic integer programs, which are difficult to solve for more than 10 stages. Scenario reduction and LP relaxation are used to obtain near optimal solutions for large problem instances. Our results show that the standard Danish mortgagor should hold a more diversified portfolio of mortgage loans, and that he should rebalance the portfolio more frequently than current practice.
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1. Introduction

1.1. The Danish mortgage market

The Danish mortgage loan system is among the most complex of its kind in the world. Purchase of most properties in Denmark is financed by issuing fixed-rate callable mortgage bonds based on an annuity principle. It is also possible to raise loans, which are financed through issuing non-callable short term bullet bonds. Such loans may be refinanced at the market rate on an ongoing basis. The proportion of loans financed by short-term bullet bonds has been increasing since 1996. Furthermore, it is allowed to mix loans in a mortgage loan portfolio, but this choice has not yet become popular.

Callable mortgage bonds have a fixed coupon throughout the full term of the loan. The maturities are 10, 15, 20 or 30 years. There are two options embedded in such bonds. The borrower has a Bermudan type call option, i.e. he can redeem the mortgage loan at par at four predetermined dates each year during the lifetime of the loan. When the interest rates are low the call option can be used to obtain a new loan with less interest payment in exchange for an increase in the amount of outstanding debt. The borrower has also a delivery option. When the interest rates are high this option can be used to reduce the amount of outstanding debt, in exchange for paying higher interest rate payments. There are both fixed and variable transaction costs associated with exercising any of these options.

Non-callable short-term bullet bonds are used to finance the adjustable-rate loans. The bonds' maturities range from 1 to 11 years and the adjustable-rate loans are offered as 10, 15, 20 or 30-year loans. Since 1996 the most popular adjustable-rate loan has been the loan financed by the one-year bond. From 2001, however, there has been a new trend, where demand for loans financed by bullet bonds with 3 and 5-year maturities has risen substantially.

1.2. The mortgagor's problem

It is known on the investor side of the financial markets that investment portfolios should consist of a variety of instruments in order to decrease financial risks such as market, liquidity and currency risk while maintaining a fixed level of return. The portfolio is also rebalanced regularly to take best advantage of the moves in the market.

The portfolio diversification principle and rebalancing is, however, not common in the borrower side of the mortgage market. Most mortgagors finance their loans in one type of bond only. Besides they do not always rebalance their loan when good opportunities for this have arisen.

There are two major reasons for the mortgagors reluctance to better taking advantage of their options (that they have fully paid for) through the lifetime of the mortgage loan:

1. The complexity of the mortgage market makes it impossible for the average mortgagor to analyze all the alternatives and choose the best.

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