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journal homepage: www.elsevier.com/locate/jfecDynamic asset allocation with stochastic income and interest rates[☆]Claus Munk^{a,*}, Carsten Sørensen^b^a School of Economics and Management and Department of Mathematical Sciences, Aarhus University, Bartholin's Alle 10, DK-8000 Aarhus C, Denmark^b Department of Finance, Copenhagen Business School, Denmark

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ABSTRACT

We solve for optimal portfolios when interest rates and labor income are stochastic with the expected income growth being affine in the short-term interest rate in order to encompass business cycle variations in wages. Our calibration based on the Panel Study of Income Dynamics (PSID) data supports this relation with substantial variation across individuals in the slope of this affine function. The slope is crucial for the valuation and riskiness of human capital and for the optimal stock/bond/cash allocation both in an unconstrained complete market and in an incomplete market with liquidity and short-sales constraints.

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1. Introduction

It is well-documented in the theoretical asset allocation literature that the inclusion of labor income has dramatic effects on the optimal long-term portfolio choice of individual investors. Several studies, e.g. Heaton and

Lucas (1997) and Cocco, Gomes, and Maenhout (2005), conclude that for an empirically reasonable insignificant correlation between labor income shocks and stock market shocks, the labor income stream is a substitute for an investment in the risk-free asset so that the financial wealth should be directed to stocks (typically, significantly levered, if possible). However, as these studies are cast in a setting where interest rates are assumed constant, they cannot distinguish short-term risk-free assets (cash deposits) from long-term risk-free assets (Treasury bonds). In order to investigate when human capital resembles a long-term bond and when it resembles cash and to assess the implications for the optimal stock/bond/cash portfolio choice, we set up, calibrate, and solve a specific model with stochastic interest rates and with a stochastic labor income that can be instantaneously correlated with interest rates, bond prices, and stock prices.

A special and important feature of our model is that the expected labor income growth rate is an affine function of the real short-term interest rate in order to

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encompass business cycle variations in wages, bonuses, and layoffs. Our calibration of the model based on PSID income data supports such a relation with a substantial variation across individuals in the business cycle sensitivity of income, i.e., the slope of the relation between expected income growth and the short-term interest rate. We demonstrate that this slope is crucial for the valuation and riskiness of the human capital and, consequently, for the optimal stock/bond/cash allocation. If the expected labor income growth is non-cyclical (zero slope), the human capital substitutes a long-term coupon bond. In that case, the optimal unconstrained investment of the financial wealth involves a large long position in stocks and significant borrowing, and will typically still involve a long position in long-term bonds for speculation and intertemporal hedging purposes. If the income is counter-cyclical (negative slope), the human capital is equivalent to a levered position in a long-term bond, and a smaller (larger) share of the financial wealth should be allocated to bonds (cash). If the income is pro-cyclical (positive slope) and the slope is exactly equal to one, the human capital will substitute for cash only. If the slope is higher than one, the human capital is like having a short position in a long-term bond and more than 100% in cash. If the slope is between zero and one, the human capital is equivalent to a moderate long position in cash and in a long-term bond. The optimal weights of the long-term bond and cash in the financial portfolio are thus highly dependent on the business cycle variations of labor income.

Throughout the paper we consider investors with time-additive power utility of consumption and terminal wealth. The dynamics of labor income, interest rates, bond prices, and stock prices are modeled by diffusion processes. First we derive a closed-form solution for the optimal consumption and investment decisions under the simplifying assumptions of no unspanned labor income risk and no portfolio constraints. While these assumptions are clearly questionable, the closed-form solution allows us to develop intuition of the economic forces at play and to understand the effect of the business cycle variations in income growth in an idealized setting. Next we allow for unspanned labor income risk and impose borrowing constraints and short-sales constraints, in which case we solve the utility maximization problem by a numerical dynamic programming technique. Our extensive numerical analysis based on the calibrated model shows that the intuition from the unconstrained, complete market version of the problem carries over to the constrained, incomplete market setting. Although the quantitative effects of the business cycle variations in income growth are dampened, the slope of the relation between expected income growth and the short-term interest rate remains an important parameter for the optimal consumption and investment decisions and, in particular, for the relative allocation between cash and long-term bonds. We illustrate the impact of this slope on the investment behavior of individuals with various levels of education using the life-cycle income profiles estimated from PSID income data, thereby generalizing the model and insights of Cocco, Gomes, and Maenhout (2005).

Let us briefly review the relevant literature for this study. As first noted by Merton (1971), long-term investors will generally hedge stochastic variations in the investment opportunity set. Stochastic interest rates are an important source of shifts in investment opportunities, and the effect of interest rate uncertainty on the optimal strategies of an investor without labor income is by now relatively well-studied. Sørensen (1999) and Brennan and Xia (2000) consider interest rate dynamics as in the Vasicek (1977) model and assume complete financial markets and constant market prices of both interest rate risk and stock market risk. They find that the optimal investment strategy of an investor with power utility of terminal wealth only is a simple combination of the mean-variance optimal portfolio, i.e., the optimal portfolio assuming investment opportunities do not change, and the zero-coupon bond maturing at the end of the investment horizon. Other studies of dynamic portfolio choice with uncertain interest rates include Brennan, Schwartz, and Lagnado (1997), Campbell and Viceira (2001), Deelstra, Grasselli, and Koehl (2000), Munk and Sørensen (2004), Sangvinatsos and Wachter (2005), and Liu (2007). None of these papers take into account a labor income stream of the investor, although labor income is the main source of funds for most individuals.

On the other hand, several papers discuss how the presence of a labor income process affects the consumption and investment decisions of individual investors in an environment of constant investment opportunities. A deterministic income stream is equivalent to an implicit investment in the risk-free asset and, hence, it is optimal to invest a higher fraction of financial wealth in the risky assets than in the no-income case; cf., e.g., Hakansson (1970) and Merton (1971). With stochastic income, but fully hedgeable income risk, the optimal unconstrained strategies can be deduced from the optimal strategies without labor income, cf. Bodie, Merton, and Samuelson (1992): given the risk structure of human capital, the financial investment is determined in order to obtain the desired overall risk exposure. Since the human capital of long-term investors is often very large compared to financial wealth, labor income has dramatic effects on their optimal portfolios. Duffie, Fleming, Soner, and Zariphopoulou (1997), Koo (1998), and Munk (2000) study (mostly by use of numerical methods) the valuation of income and the optimal consumption and investment strategies of an infinite-horizon, liquidity constrained power utility investor with non-spanned income risk. The presence of liquidity constraints can significantly decrease the individual's implicit valuation of the future income stream and, hence, dampen the quantitative effects of income on portfolio choice. Other recent papers on consumption and portfolio choice with stochastic income include He and Pagès (1993), Heaton and Lucas (1997), Viceira (2001), Constantinides, Donaldson, and Mehra (2002), and Cocco, Gomes, and Maenhout (2005). Besides working with constant investment opportunities, the concrete models with stochastic income in these papers assume a single risky asset, interpreted as the stock market index. Since different risky assets will have different correlations with the labor income of a given

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