A Labor Market-Based Theory of Interest Rates

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March 15, 2019

Abstract

We propose a theory of real interest rates in which frictions in labor markets are a key determinant of interest rate risk. In our model, firms face labor adjustment costs due to search frictions. An increase in the number of job-openings posted by firms in the current period increases the expected time to fill job-openings in future periods. In general equilibrium, this has a first-order effect on the distribution of consumption risk faced by the representative household, which in turn influences the household’s demand for holding long-term, default-free bonds. We show that the risk-premium of a long-term bond, over a holding period shorter than its maturity, is positive in this economy. Our model predicts the size of this premium to be inversely related to hiring rates and changes in labor market tightness. We test our model’s predictions in US data and find support.

JEL numbers: E24, E43, G12, J63.

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1 Introduction

The study of the drivers of interest rates is of central importance in financial economics. We propose a theory of real interest rates in which frictions in labor markets are a key determinant of interest rate risk. In our model, firms face labor adjustment costs due to search frictions. An increase in the number of job-openings posted by firms in the current period increases the expected time to fill job-openings in future periods. In general equilibrium, this has a first-order effect on the distribution of consumption risk faced by the representative household, which in turn influences the household’s demand for holding long-term, default-free bonds. We show that the risk-premium of such a bond, over a holding period shorter than its maturity, is positive in this economy. Our model predicts this premium to be larger when hiring rates and changes in labor market tightness are lower.\textsuperscript{1} Our model, therefore, links bond return predictability to the real economy. We test our model’s predictions in US data and find support.

Our model features firms which use labor as an input to production. In order to hire a worker, a firm must post a job-opening. As is standard in search-based models, we assume that the firm must pay a per-period cost to maintain the opening. The presence of search frictions implies that it takes time to fill a job-opening. The firm’s expected cost of hiring a worker thus depends on the expected time to fill an opening. The latter depends on the number of job-openings posted by firms relative to the number of job-seekers. An increase (decrease) in the number of openings posted by firms in the current period, ceteris paribus, decreases (increases) the number of job-seekers in future periods. This alters future hiring costs by changing the expected time to fill future openings. In short, shocks to the demand

\textsuperscript{1}Labor market tightness is the ratio of the number of job-openings posted by firms to the number of job-seekers. It measures the excess demand for workers.
for workers in the current period are propagated across time by search frictions. We show that, in equilibrium, this affects the price of long-term bonds. We explain the intuition for our results next.

Our model is a production-based model featuring a representative investor with power utility. Shocks to labor productivity is the only shock in our model. These shocks are mean-reverting, and for simplicity, we assume that they take two values. Bonds require a positive risk premium in this economy for the standard reason: shocks to the growth of the equilibrium marginal utility process co-vary negatively with shocks to expected growth in marginal utility. Our model, however, avoids the puzzle highlighted by Backus, Gregory, and Zin (1989), namely that power utility preferences would seem to require consumption growth to have a counter-factually large negative auto-correlation. The negative correlation in consumption growth between states with different productivity is countered by a positive correlation in consumption growth between states with the same productivity.\(^2\)

Our result of a negative relationship between bond risk-premium and labor market variables (hiring rates and tightness) arises because states associated with higher (lower) cost of posting job-openings are associated with a higher (lower) volatility of consumption growth. To see this, consider again the scenario in which the economy transitions to a low productivity state. All else equal, a reduction in the number of job-openings posted in the current period leads to an increase in unemployment and therefore the number of job-seekers in the next several periods. This lowers the expected time to fill future job-openings. Firms are therefore able to respond more aggressively to changes in future investment opportunities. The net result is an increase in the volatility of equilibrium hiring rates, output, and consumption over the next several periods. Consequently, both the household’s equilibrium marginal utility

\(^2\)The size of the employed workforce is a state-variable in our model since it captures congestion in labor markets. States with the same productivity are differentiated by the size of their workforce.
and the holding period return of the bond, become more volatile. Put differently, the risk premium on the bond increases when the hiring rate and tightness declines because of an increase in both the price and quantity of risk.

Our model generates time-varying risk premium from changes in the number of job-openings posted by firms. Figure 1 shows that the number of vacancies posted by firms in the US (normalized by the number of employed workers) is pro-cyclical with significant volatility. From this figure we see that the incentive for firms to post openings varies significantly over time. There are many potential reasons for this. As a modeling device, we assume that the source of this variation is a shock productivity. Our findings are robust to alternate sources of such variation, such as shocks to to the per-period cost of maintain a job-opening.3

The expectations hypothesis is violated in our model and we report results of Fama and Bliss (1987) regressions. We purposefully keep preferences in our model simple, and assume that the representative household has a constant relative risk aversion (CRRA) over consumption. This allows us to focus on the effect of labor market frictions on bond returns. Even with a CRRA preference, our model-implied estimates for the coefficients of the Fama-Bliss regressions capture roughly one tenth of the magnitude of their data counterpart. Furthermore, this result highlights that with adjustment costs induced by labor market frictions, it is possible to generate violations of the expectations hypothesis without the need to have counter-factual negative persistence in consumption growth.4 Allowing for richer preferences of the household is likely to improve the quantitative fit of our model with respect to the Fama-Bliss regressions. However, we believe that such extensions would not alter the main economic mechanism of our model.

3 Vacancy posting costs also generate positive, time-varying excess bond returns without generating consumption growth that is negatively auto-correlated. Results available upon request.
4 Since consumption is endogenously chosen in our model, the result of Backus, Gregory, and Zin (1989) does not apply here.
Our model predicts that previous employment growth and changes in labor market tightness predict subsequent bond excess returns. We test these predictions using U.S. monthly data for the period 1964-2016. We find that a one standard deviation decrease in employment growth over the past month is associated with a 1% increase in excess returns for an equal weighted portfolio of two to five year bonds over the next year. The $R^2$ of the univariate regression is about 8%. The magnitude of the slope coefficient is increasing across bond maturities. Similarly, a one standard deviation decrease in labor market tightness is associated with an average increase of 0.54% in excess returns; the corresponding $R^2$ for the univariate regression is 2.2%. This finding is robust to the inclusion of known predictive variables.

We further test our model’s channel by using past changes in labor market tightness to predict changes in future economic activities. In the data, as in our model, a decrease in labor market tightness predicts an increase in the future volatility of consumption growth, as well as a slowdown in future economic activity (lower growth of employment, output, and consumption).

**Literature Review.** Our paper connects the literature on the risk premium of long-term risk-free bonds with the literature which examines the impact of labor market frictions on asset prices.

Empirical evidence on the time-variation in the risk premium of long-term bonds is well established (see, e.g., Fama and Bliss (1987), Campbell and Shiller (1991), and Cochrane and Piazzesi (2005)). There are two approaches to rationalize this finding. The first approach is based on rich preference specifications of the representative household, since it has been known from early work by Backus, Gregory, and Zin (1989) that consumption-based models
with time-separable CRRA preferences can neither account for the sign nor the magnitude of observed bond risk premia. Examples of consumption based models which can successfully account for observed bond-premium are the habit-based model of Wachter (2006) and the models of Piazzesi and Schneider (2007) and Bansal and Shaliastovich (2013) in which the household has recursive preferences. The second approach rationalizes time-varying risk premium using production-based models in which this premium is determined as a consequence of investment decisions of forward looking firms. Our production-based model falls in this group.

Examples of production-based models which link bond risk premia to investment in physical capital are Cochrane (1988) and Jermann (2013). There are two important differences with these papers and our paper. First, while these papers connect bond premium to capital investment, we connect bond premium to labor market variables. We view this as important, because as we document, aggregate hiring rates and changes in labor market tightness predict the excess return of long-term bonds in US data. In contrast, the investment rate, measured using private non-residential investment, does not appear to have much predictive ability for excess bond returns.\footnote{These results are available upon request.} While this could be due to measurement issues, at the very least, it suggests that investigating the connection between labor markets and risk premium is worthwhile. A second difference is that while these papers recover state prices (and therefore risk premia) from an exogenously assumed process for investment growth, our model provides a general equilibrium perspective by linking such firm decisions directly to the representative household’s savings decision.

To the best of our knowledge, the only prior paper which has examined the link between labor markets and bond-risk premium is Rudebusch and Swanson (2008). Using a model
with quadratic labor adjustment costs and two other forms of wage rigidities, these authors conclude that labor market frictions do not appear promising. The key difference between our set-up and theirs is that our assumption of labor market search frictions in the spirit of Diamond-Mortensen-Pissarides (Diamond, 1982; Pissarides, 1985; Mortensen and Pissarides, 1994) results in endogenous adjustment costs which are state-dependent and mean-reverting in nature. We find that this is of first-order importance in generating substantial predictability in bond excess returns. Moreover, we provide empirical evidence which is supportive of our channel.

Other factors which influence bond risk premia include bond supply (Greenwood and Vayanos, 2014) and banks’ interest rate exposure (Haddad and Sraer, 2018). Finally, there is also a vast literature on reduced form affine models of the term structure that includes macroeconomic factors (see, e.g., Ang and Piazzesi (2003), Joslin, Priebsch, and Singleton (2014)).

The importance of search frictions for equity returns has been pointed out by Petrosky-Nadeau, Zhang, and Kuehn (2018) for the aggregate stock market, and by Kuehn, Simutin, and Wang (2017) in the cross-section. More generally, the importance of labor market frictions in the context of equity-returns has been highlighted in Belo, Lin, and Bazdresch (2014), Donangelo (2014), Favilukis and Lin (2015), Belo, Donangelo, Lin, and Luo (2017), and Liu (2018). In addition, Favilukis, Lin, and Zhao (2018) point out the impact of labor market frictions on returns of defaultable bonds.
2 Model

In this section, we present a general equilibrium model of real interest rates in which labor market frictions are a key determinant of interest rate risk. In the model, workers serve as the only input to produce a single consumption good. A representative firm posts vacancies in order to hire workers, with the hiring process being subject to labor market search frictions. We assume that labor productivity varies over time and derive its equilibrium consequences for interest rates.

2.1 The Economy

The economy is set in discrete time and over an infinite horizon. There is a unit mass of ex-ante identical workers who are able to perfectly share labor income risk.\footnote{This is a standard assumption in the labor search literature. For example, see Merz (1995) and Andolfatto (1996), as well as Shimer (2010) for a textbook treatment.} Individual workers can therefore be aggregated to a single representative household. The representative household has time-separable iso-elastic preferences and derives utility

\[ J_t = \mathbb{E}_t \left[ \sum_{k=0}^{\infty} \frac{1}{1 - \gamma} \beta^k C_{t+k}^{1-\gamma} \right] \]

from the consumption flow of the single good, where \( \beta \) is the time-preference parameter and \( \gamma \) is the coefficient of relative risk aversion. Standard household optimality conditions imply that the stochastic discount factor is given by

\[ M_{t,t+1} = \beta \left( \frac{C_t}{C_{t+1}} \right)^\gamma, \]

where

\( M_{t,t+1} = \frac{\mathbb{E}_{t+1} C_{t+1}}{C_t} \) is the stochastic discount factor. This is the probability that a worker will still be working in period \( t+1 \) given that they were employed in period \( t \).
where $C_t$ is the equilibrium level of consumption of the representative household.

The production side consists of a unit mass of ex-ante identical firms. They have identical investment opportunities and face the same cost of adjusting the size of its work-force. In equilibrium firms make identical decisions which allows us to aggregate the cross-section into a single representative firm. The representative firm produces the consumption good using a linear production technology with labor as the sole input:

$$Y_t = z_t N_t,$$

where $N_t$ is the total number of workers who are employed in that period. Labor productivity, $z_t$, depends on the aggregate state of the economy $s$. Motivated by findings in the term-structure literature that the short interest rate and the market price of risk follows a two-state process related to business cycles (Hamilton, 1988; Bansal and Zhou, 2002), we assume that $s$ takes two values $s = \{1, 2\}$. The two states evolve according to the Markov transition probability matrix $\Pi$ with elements $\pi_{ij} = \text{prob}(s_{t+1} = j|s_t = i)$.

Each period, the representative firm posts $V_t$ vacancies each period after paying a cost $\kappa$ per vacancy. This is the sole form of investment in our model. A total of $U_t$ workers (the unemployed) apply for these jobs. Due to search frictions, it takes time to fill vacancies. In particular, a total of $m(U,V)$ matches are successfully formed. Following den Haan, Ramey, and Watson (2000), we parameterize the matching function to have the following form:

$$m(U_t, V_t) = \frac{UV}{(U_t^\dagger + V_t)^\xi},$$

where $U_t^\dagger$ is the number of unemployed workers.

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7This parameterization has the convenient property that the resulting meeting probabilities automatically lie between 0 and 1.
with $\iota > 0$. The contact rate between unemployed workers and vacancies depends on the ratio of the number of vacancies posted to the number of job-seekers. This quantity, known as labor market tightness, $\Theta \equiv V/U$ captures current labor market conditions. In particular, the probability of an unemployed worker successfully finding a job is $f(\Theta) = m(U, V)/U = (1 + \Theta^{-\iota})^{-\frac{1}{\iota}}$, while the probability of the firm filling a vacancy is $g(\Theta) = m(U, V)/V = (1 + \Theta^\iota)^{-\frac{1}{\iota}}$.

Each period, a fraction $s$ of employed workers lose their jobs, while a fraction $f(\Theta_t)$ of job-seekers find a job. The number of employed workers evolves according to the law of motion

$$N_{t+1} = (1 - \chi)N_t + f(\Theta_t) (1 - N_t).$$

Employed workers are paid wages determined using a generalized Nash-bargaining protocol described below. Unemployed workers are paid the amount $b$ for each period of unemployment. These unemployment benefits are funded by lump sum taxes.

**Timing of events.** The timing of events within each period is as follows:

(i) At the start of period $t$, there is a mass $N_t \in [0, 1]$ of previously employed workers.

(ii) Nature draws the aggregate state $s_t$ according to its law of motion.

(iii) The representative firm posts a total of $V_t$ vacancies. The mass, $U_t = 1 - N_t$, of unemployed workers searching for jobs are then matched to vacancies according to the matching function (4). A worker who gets hired this period starts producing from next period. Wages are set according to a generalized Nash bargaining rule with workers capturing a fraction $\eta$ of the surplus.
(iv) Output is realized. Wages are paid and consumption takes place. Unemployed workers receive unemployment benefits, which are financed through lump sum taxation.

(v) Existing matches (excluding newly formed ones) exogenously separate with probability $s$.

**Firm’s problem.** The representative firm chooses the number of vacancies to post each period to maximize the present-discounted value of dividends

$$D_t = Y_t - w_t N_t - \kappa V_t,$$

where output is given by (3), $w_t$ is the wage paid to each employed worker and $V_t$ is the number of vacancies posted by the firm.

The representative firm chooses the number of vacancies $V_t$ subject to a non-negativity constraint (i.e. $V_t \geq 0$). In recursive form, the firm’s Bellman equation is

$$F(s_t, N_t) = \max_{V_t \geq 0} D_t(s_t, N_t) + \mathbb{E}_t [M_{t,t+1} F(s_{t+1}, N_{t+1})],$$

where future dividends are discounted using the stochastic discount factor (2), and vacancies are chosen subject to the law of motion

$$N_{t+1} = (1 - \chi) N_t + g(\Theta_t) V_t,$$  

In (8), firms take labor market tightness $\Theta_t$ as given.

The firm’s decision to post a vacancy depends on the value of a vacancy relative to the unit cost of posting a vacancy, and vacancies will be posted as long as the former remains greater.
Under the linear technology (3), the marginal value of an additional unit of employment to the firm, \( \bar{F}(s_t, N_t) := \frac{\partial F(s_t, N_t)}{\partial N_t} \), satisfies the following Bellman equation:

\[
\bar{F}(s_t, N_t) = 1 - w_t + (1 - \chi) \mathbb{E}_t \left[ M_{t,t+1} \bar{F}(s_{t+1}, N_{t+1}) \right].
\] (9)

The ex-ante value of a vacancy in state \((s_t, N_t)\) is then \( g(\Theta(s_t, N_t)) \mathbb{E}_t \left[ M_{t,t+1} \bar{F}(s_{t+1}, N_{t+1}) \right] \). This takes into account the state-dependent vacancy-filling probability \( g(\Theta(s_t, N_t)) \) along with our timing convention that a newly matched worker only begins working at the start of the next period. An unfilled vacancy is worthless ex post. We assume free entry which implies that the equilibrium amount of vacancies posted is determined as the solution to the following complementary slackness problem:

\[
\kappa(s_t) \geq g(\Theta(s_t, N_t)) \mathbb{E}_t \left[ M_{t,t+1} \bar{F}(s_{t+1}, N_{t+1}) \right],
\] (10)

with equality if and only if total vacancies \( V_t = V(s_t, N_t) \) is strictly positive.

**Household’s problem.** The representative household maximizes utility (1) subject to the budget constraint

\[
C_t = D_t + w_t N_t + bU_t - T_t.
\] (11)

The representative household owns the representative firm and therefore receives dividend income (6). Employed workers are paid wages at rate \( w_t \) while unemployed workers receive unemployment benefits of \( b \). Aggregate unemployment benefits are financed with lump-sum taxes totalling \( T_t = bU_t \).

The value of an additional unit of employment and unemployment to the representative household are given by \( J_e(s_t, N_t) := \frac{\partial J_t}{\partial N_t} \) and \( J_u(s_t, N_t) := \frac{\partial J_t}{\partial U_t} \), respectively, where
$J_t$ is the representative household value function (1). The marginal value of employment to the representative household satisfies:

$$J_e(s_t, N_t) = w(s_t, N_t) + \mathbb{E}_t \left[ M_{t,t+1} \left( \chi J_u(s_{t+1}, N_{t+1}) + (1 - \chi) J_e(s_{t+1}, N_{t+1}) \right) \right].$$  \hspace{1cm} (12)

An employed worker receives wage $w(s_t, N_t)$, and the match continues so long as the exogenous separation shock (which occurs with probability $s$) does not materialize.

The value of an additional unemployed worker to the representative household is:

$$J_u(s_t, N_t) = b + \mathbb{E}_t \left[ M_{t,t+1} \left( f(\Theta_t) J_e(s_{t+1}, N_{t+1}) + (1 - f(\Theta_t)) J_u(s_{t+1}, N_{t+1}) \right) \right].$$  \hspace{1cm} (13)

An employed worker obtains unemployment benefit $b$ in the current period and searches for a new job. With probability $f(\Theta_t)$, the unemployed worker is matched to a vacancy and starts producing from the following period; otherwise, the worker remains unemployed.

Wages. Wages are determined by standard Nash bargaining. The total match surplus $S(s_t, N_t) \equiv J_e(s_t, N_t) - J_u(s_t, N_t) + \bar{F}(s_t, N_t)$ is split between the representative household and the representative firm. We assume that the representative household has bargaining power $\eta \in [0, 1]$. In equilibrium, his share of the total match surplus is $\eta S(s_t, N_t)$. The firm gets $\bar{F}(s_t, N_t) = (1 - \eta)S(s_t, N_t)$. This characterizes wages:

$$w(s_t, N_t) = \eta + (1 - \eta)b + \eta \kappa \Theta(s_t, N_t).$$  \hspace{1cm} (14)

Proof: See Appendix A.1.
Equilibrium. The notion of equilibrium for the economy is standard: all value functions satisfy their respective Bellman equations (cf equations (9), (12), and (13)), wages are set according to the Nash bargaining rule (14), and labor market tightness is determined according to the free entry condition (10). Furthermore, goods market clearing implies that equilibrium consumption is equal to

\[ C_t = Y_t - \kappa V_t. \]  

(15)

3 Quantitative Analysis

In this section, we quantify the magnitude of bond risk premia and differences in bond risk premia across aggregate states. We first describe our choice of parameters and report unconditional moments of key labor market quantities and asset prices. Next we discuss how our model links bond excess return predictability to labor market quantities. Finally, we discuss the effect of productivity shocks on real quantities, namely aggregate output, employment, and consumption.

3.1 Calibration

We calibrate our model by targeting the standard set of labor market moments described below. We simulate our model at monthly frequency using the parameters shown in Table 1. Our model-implied labor market moments, the volatility and auto-correlation of consumption growth, and the moments of bond returns are shown in Table 2, together with the data counterparts.

Before we discuss our choice of the Markov transition probabilities of our 2-state model,
following Barton, David, and Fix (1962), we parametrize this transition matrix by

$$
\pi_{ij} = (1 - \lambda)\pi_j + \lambda\delta_{ij}.
$$

(16)

$\pi_j$ is the long-run equilibrium distribution of state $j$, while the parameter $\lambda$ captures the persistence of aggregate shocks ($\lambda = 0$ corresponds to i.i.d states).

We identify the two productivity states with a typical boom and a bust. We define a boom-busts using the hp-filtered series monthly series for US GDP in logs (using a smoothing parameter of 1600) and define a boom to be realizations of this series above its 80-th percentile. This implies $\pi_2 = 0.8$ and $\pi_1 = 0.2$. We estimate the Markov transition probability, by fitting the hp-filtered log-gdp series to a two-state Markov chain and obtain $\lambda = 0.889$. We choose the size of the shock, $z_2 - z_1$ to match the volatility of unemployment and obtain $z_2 - z_1 = 0.025$.

There are five different labor market parameters. Two of these, the job-separation rate $\chi$ and the curvature of the matching function $\iota$ are estimated directly from the data. The job-separation rate $\chi = 3.2\%$ matches the average monthly job-separation rate of non-farm workers reported by the US Bureau of Labor Statistics over the period 2000—2018. We obtain a curvature of $\iota = 1.24$ for the matching function (4) by minimizing the sum square error of the difference between the model implied job finding probability $f(\Theta_t)$ and its empirical counterpart over the period 1964—2016. Estimates of $b$ vary widely in the literature—between $b = 0.955$ by Hagedorn and Manovskii (2008) to $b = 0.4$ by Shimer (2005). Our parameter choice $b = 0.88$ coincides with that obtained by Christiano, Eichenbaum, and Trabandt (2016).

We choose the vacancy posting cost $\kappa = 1.6$ to target the mean job-finding rate. Our
model implied mean job-finding rate is 0.52 compared to 0.45 in the data. The volatility of labor market tightness in our model is 0.13 and 0.10 in the data. Finally, we choose the worker’s bargaining power $\eta = 0.02$ to target the volatility of wages to output. This value is 0.44 in the data and 0.33 when we simulate our model.

We choose the representative household’s time preference parameter, $\beta = 0.9985$, to target the mean risk-free rate over a one-month horizon. This value is 1.23% in the data and 1.30% in our model (both values are annualized). We choose the household’s risk-aversion parameter $\gamma = 10$ to match the volatility of consumption; the latter value (quarterly) is 0.80% in the data and 0.95% in our model. The volatility of the one-month risk-free rate, which is not a target, is 2.50% in our model and 1.78% in the data.

### 3.2 Bond Risk Premium and Labor market quantities

In this sub-section, we provide the intuition for positive risk premium of long-term bonds in our model. We begin by discussing the vacancy posting policies of the representative firm and its implications for aggregate quantities. Next we discuss the implications of such policies for the equilibrium marginal utility process of the representative investor.

**Firms’ Vacancy Posting Policies** Panel A of Figure 2 shows that firms post less vacancies when productivity is low. In this and all following figures, the solid line corresponds to the state associated with low productivity ($s = 1$), while the dotted line corresponds to the state associated with high productivity ($s = 2$).

Changes in the number of vacancies posted by firms directly affects both future employment and current (and future) labor market tightness. Panel B shows the employment level in the following period. From this figure we see that the state associated with low (high)
productivity has negative (positive) employment growth (the dot-dash, black line is the
45-degree line representing $N_{t+1} = N_t$). Similarly, panel C shows that a reduction in the
number of vacancies posted by firms in the low $z$ state leads to an immediate reduction in
labor market tightness in that period.

Panels D and E show the job-finding probability of job-seekers and the job-filling probability
of firms. Both of these are related to tightness through the matching function—the former
is an increasing function of tightness, while the latter is a decreasing function of tightness.
Last, but not the least, panel F shows the wage in the two states as a function of the size of
the labor force.

**Unconditional Bond Excess Returns**  In our model, bonds earn a positive risk premium
because their returns co-vary negatively with the marginal utility process of the representative
household. Table 3 shows the model-implied excess returns. We show below that long-term
bonds earn a risk premium because they are poor hedges against consumption risk. For
instance, the excess return on the two-year bond (first row) over a holding period of one year
in the data is 0.48%. Our model generates an unconditional mean (annualized) excess return
of 0.44%. We report the excess returns for bonds of maturities 4 and 5 years in the two
remaining rows. We see that our model-implied excess bond return increases with maturity,
as in the data, however this increase is more modest in our model in comparison to the data.

To see how our model generates a positive bond risk premium, consider the Euler equation
of the representative household. The excess return of a bond which matures in $n$ periods,
over a holding period $h$, is

$$
\mathbb{E}_0 R_{x_h}^{(n)} = -R_h^{(h)} \text{Cov}_0 \left( M_{0,h}, \mathbb{E}_h R_h^{(n)} \right)
$$

\begin{equation}
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\end{equation}
where $R_h^{(h)} = 1/P_0^{(h)}$ is the $h$-period risk-free rate, the excess return $R_{x_h}^{(n)} = R_{0,h}^{(n)} - R_h^{(h)}$, the realized bond return after $h$ periods is $R_h^{(n)} = P_h^{(n-h)}/P_0^{(n)}$, and where $P_t^{(n)}$ is the time-$t$ price of a bond which matures $n$ periods later.

As we show below, the bond is not a poor hedge in all possible scenarios. To analyze the contribution of each path to bond risk premium, we decompose (17) over all paths. Our assumption of two possible states, $s = \{s_1, s_2\}$ makes counting and listing the paths simple. In total, there are $2^h$ possible paths over a holding period of $h$. However, since the states $s$ are quite persistent (both in the data and in our model) only $h + 1$ of them are sufficiently likely to occur. These include one path in which the state remains in its initial state (i.e. no transitions occur) at the end of $h$ periods and $h$ paths in which the state switches only once. In our discussion below, we will refer to them as “simple” paths since they involve at most a single transition of $s$.\(^8\)

As an example, we consider the excess return of a bond maturing in $n = 12$ months over a $h = 6$ month holding period. The results are shown in Figure 3. At $t = 0$, when the bond is bought, the economy is assumed to be in the high productivity state. Panel A shows the possible values of $N$ at the end of the holding period (i.e. at $t = 6$) for each of the $6 + 1$ simple paths discussed above. Each point in this figure corresponds to a single path identified by the timing of state-switch. We see that the earlier the economy transitions to the low productivity state, the lower the final number of workers employed. This is because firms post fewer vacancies when productivity is low (see panel A of Figure 2). With fewer openings, fewer unemployed workers find jobs, and since the job-loss rate is constant, the size of the employed workforce declines more along paths in which the economy stays longer in the low productivity state.

\(^8\)Note that the size of the work-force, which is the other state-variable takes on different values along each path.
Panel B of Figure 3 shows the probability of each of the simple paths. The cumulative probability of these paths is 97.45%. This shows that the inaccuracy from not ignoring paths along which there are more than one transition of the aggregate state is not large.\footnote{Of course, over longer holding periods, paths with two or more transitions start contributing more.} We note that the results reported in Table 3 do not use this approximation—they are exact and account for all paths.

Panel C shows the contribution of each of these simple paths to the risk-premium (17). Each square dot shows the household’s marginal utility $M_{0,h}$ at the time of selling the bond (i.e. at $t=6$) along that path. The triangular, red dots show the expected marginal utility from the time of selling the bond at $t=6$ and when the bond matures at $t=12$. The latter quantity, is equal to the selling-price of the bond up to a constant of proportionality.\footnote{Both quantities are de-meaned. For example, the de-meaned marginal utility is $\delta M_{0,h} = M_{0,h} - \bar{M}_{0,h}$ where $\bar{M}_{0,h}$ is the mean marginal utility over all possible paths. Making this adjustment makes it easier to read off the sign of the contribution of each path to the covariance on the right-hand-side of (17).}

A decomposition of the risk premium along the simple paths reveals two features. First, paths in which the economy transitions right after the purchase of the bond contributes most to the positive risk-premium. For example, consider the path in which the economy transitions to the low-productivity state in the period following the purchase, i.e. at $t=1$. Since productivity stays low over the next 5 periods, employment at the time of selling the bond will be very low. In addition, since productivity is also low, output and consumption are lowest among all the possible paths. This high level of marginal utility is shown by the square dot in panel C corresponding to $t=1$. The triangular dot corresponding to this path shows low expected growth of marginal utility between the time the bond is sold and when it matures.

On the other hand, if the economy transitions to the low productivity state closer to the
date the bond is sold, say at $t = 5$, the expected growth rate in marginal utility is lower. This can be understood as follows. Along such a path, productivity stays low for a shorter time. For this example, it stays low only for one period. Therefore, $N$ does not decline as much (see panel A of Figure 3). In our model, the expected growth of marginal utility is an increasing function of $N$. Figure 4 provides the intuition. Panel A of this figure shows the increasing relationship with $N$. This arises because the expected growth rate of consumption is high when $N$ is low (panel B). Panel C shows that risk in consumption growth declines for higher $N$; however quantitatively, this does not offset the contribution of the growth channel shown in B.

The second feature that is apparent from panels A and B of Figure 3 is that consumption growth does not have a large negative auto-correlation, even though the bond risk premium is positive.

### 3.3 Return Predictability

We showed above that long-term bonds have a positive beta in our model and therefore earn a positive risk-premium. In this sub-section, we show that this premium is time-varying—it is higher (lower) in the state in which productivity is lower (higher). This negative relationship between labor market tightness and excess returns is shown in Table 4. The table shows the model-implied excess returns for the two, three, four, and five year maturity bonds over a holding period of one year. Consider the two-year bond (first row). For example, when the economy transitions from the high productivity state ($s = 2$) to the low productivity state ($s = 1$), labor market tightness declines by 0.30. The excess return of the bond increases from 0.33% to 0.92% (both annualized). This negative relationship between changes in labor market tightness and the risk-premium is the key prediction of our model.
The intuition for the inverse relationship between labor market tightness and risk premium arises is as follows. In Panel A of Figure 5, we show the risk premium of the bond as a function of our model’s two state variables, $N$ and $s$. We see that the risk-premium is higher in the state in the low productivity state (shown by the solid, red line). In this state, labor market tightness is low (see panel C of Section 3.2) as is (realized) employment growth. In other words, our model predicts excess returns of this 2 year bond (over a holding period of one year) to be high when labor market tightness and employment growth are low. We test these two predictions of our model in Section 4 and find support.

Excess returns are higher in the low productivity state for two reasons: First, the investor’s marginal utility (holding period of the bond) is more volatile in this state. This is shown in panel B of Figure 5. Second, holding period returns are more volatile in this state, as shown in panel C of this figure. We provide the intuition for each of these results next.

The intuition for a higher volatility of the investor’s marginal utility in the state associated with lower productivity is as follows. Suppose the economy is in this state when the investor buys the bond. If the economy were to switch to the high productivity state $z_2$ over the holding period of the bond, firms would post vacancies at a higher rate after the switch because: (a) investment opportunities are better, and (b) the probability of finding workers is higher since the economy started out with a lower value of market tightness. This implies a much larger range of $N$, and therefore, output and consumption. The intuition for higher volatility of returns is closely related and results from the fact that there is greater variability in $N$ at $t = 6$.

**Violation of Expectations Hypothesis:** To test for violation of the expectation hypothesis in our model, we performed the equivalent of the Fama-Bliss regression Fama and Bliss
(1987) for a two-year (24 month) bond over a holding period of 12 months

\[ r_{x_{t+12}}^{(24)} = a + b_{FB}(f_t^{(24)} - y_t^{(12)}) + \epsilon_{t+1} \quad (18) \]

where \( r_{x_{t+12}}^{(24)} \) is the log-excess return of the two-year bond over a holding period of 12 months, \( f_t^{(24)} \) is the forward rate to borrow for 12 months beginning 12 months from period \( t \), and \( y_t^{(12)} \) is the 12 month risk-free rate. In other words, we estimated the amount of predictability in one-year excess returns of a two-year bond using the corresponding forward-yield spread. The expectations hypothesis predicts the value of the coefficient \( b_{FB} \) to be zero. The model-implied estimate for our calibration is 0.085, which is about 11% of its data-counterpart. Violations of the expectation hypothesis are quantitatively small in our model because of our choice to use power-utility for the household’s preference. We conjecture that if, instead, we were to use richer preference specifications such as habit, this would be much closer to the counterpart in the data. However, although the model would probably have performed quantitatively better, it would not provide additional insight into our channel.

4 Empirical Evidence

In this section, we document a robust inverse relationship between changes in labor market tightness and future excess bond returns. We also document a similar robust inverse relationship between changes in aggregate employment and future excess bond returns. We also provide evidence for our model’s economic mechanism by documenting that changes in labor market tightness positively predict future movements in consumption, employment, and output, while negatively predicting future changes in consumption growth volatility.
4.1 Data

Our sample period is 1964-2016. A summary of data sources is given in Appendix B.

**Measuring labor market conditions.** Our asset pricing tests make use of two labor market based measures: changes in labor market tightness $\Delta \Theta_t$, and aggregate employment growth $\Delta \log N_t$. These choices are directly motivated by our model. In our model, the equilibrium marginal utility process $\beta C_t^{-\gamma}$ is a function of two state variables: $\kappa(s_t)$ and $N_t$. As a result, the log linearized version of the pricing kernel (2) has form

$$
\log M_{t,t+1} \approx m_0 + m_1 \Delta \kappa(s_{t+1}) + m_2 \Delta \log N_{t+1}
$$

where $m_0$, $m_1$, and $m_2$ are all constants. Asset pricing tests based on the above log-linearized pricing kernel cannot be directly implemented because shocks to hiring costs $\Delta \kappa(s_t)$ are not directly observable in the data. Therefore, we use changes in labor market tightness $\Delta \Theta_{t+1}$ to replace shocks to hiring costs $\Delta \kappa(s_t)$ in our final asset pricing tests. This is because our model suggests that changes in labor market tightness $\Delta \Theta_{t+1}$ is a good observable proxy for shocks to hiring costs $\Delta \kappa(s_{t+1})$.

We obtain unemployment rates from the Bureau of Labor Statistics. We measure job vacancies using the composite Help Wanted Index from Barnichon (2010); this index combines both print and online help wanted advertising. Labor market tightness is then constructed as

$$
\Theta_t = \frac{\text{Help Wanted Index}_t}{\text{Unemployment Rate}_t}.
$$

The ratio of available jobs to those searching for jobs is high in a tight labor market so that job seekers find jobs quickly while employers take longer to fill jobs. In addition, we construct
employment growth $\Delta \log N_t$ based on monthly employment levels reported by the Bureau of Labor Statistics.

Figure 6 plots our two labor market based measures, $\Delta \Theta_t$ and $\Delta \log N_t$. Panel A of Table 5 reports summary statistics for these two measures along with statistics for other macroeconomic variables. The additional macroeconomic series we consider in our robustness checks are: real economic activities as measured by the three month moving average of the Chicago Fed National Activities Index (CFNAI), CPI inflation (INF), the Federal Funds rate (FFR), the maturity weighted debt to GDP ratio (MWDGDP) taken from Greenwood and Vayanos (2014), the equity market dividend to price ratio (DP), and the BAA-AAA credit spread (CS). All series are monthly and are for the period 1961m1-2016m12, except for the Chicago National Activities Index (available from 1967m5 onwards) and the Greenwood and Vayanos (2014) maturity weighted debt to GDP series (available up until 2007m12).

**Bond returns.** We measure bond returns using Fama-Bliss data (available from CRSP) of one through five year zero coupon bond prices. We denote the log excess holding period return from buying an $n$-year zero coupon bond at time $t$ and selling it as an $n-1$ year zero coupon bond at time $t+1$ as

$$rx^{(n)}_{t+1} = \log P^{(n-1)}_{t-1} - \log P^{(n)}_t - y^{(1)}_t,$$

where $P^{(n)}_t$ denotes the price of an $n$-year zero coupon bond at time $t$, and $y^{(1)}_t = - \log P^{(1)}_t$ is the one year yield at time $t$. We also denote by

$$\overline{rx}_{t+1} = \frac{1}{4} \sum_{n=2}^{5} rx^{(n)}_{t+1}$$

(21)
the average log excess holding period return across maturities.

For our robustness checks, we additionally construct the Cochrane-Piazzesi factor following Cochrane and Piazzesi (2005). In particular, we construct the factor as 
\[ CP_t = \hat{\gamma}_0^{CP} \gamma^{CP} y_t^{(1)} + \hat{\gamma}_1^{CP} f_t^{(2)} + \ldots + \hat{\gamma}_5^{CP} f_t^{(5)}, \]
where \( f_t^{(n)} = \log P_t^{(n-1)} - \log P_t^{(n)} \) denotes the log forward rate at time \( t \) for loans between time \( t + n - 1 \) and \( t + n \), and the weights are obtained by fitting the regression \( \bar{r}_x_t = \gamma_0^{CP} + \gamma_1^{CP} y_t^{(1)} + \gamma_2^{CP} f_t^{(2)} + \ldots + \gamma_5^{CP} f_t^{(5)} + \varepsilon_t^{CP} \) over our sample period.

Panel B of Table 5 reports the summary statistics. The bond excess return series are monthly observations of annual returns.

**Growth in economic activities.** To investigate the economic mechanism of our model, we consider the relationship between changes in labor market conditions with future growth in employment, output, and consumption. We also investigate the relationship between changes in labor market conditions and consumption growth volatility. Data for these series are quarterly and are downloaded from FRED. We extract quarterly consumption growth volatility based on an AR(1)-GARCH(1,1) specification for consumption growth:
\[
\Delta \log C_{t+1} = a_0 + a_1 \Delta \log C_t + \varepsilon_{\Delta \log C_{t+1}}, \quad \varepsilon_{\Delta \log C_{t+1}} \sim N(0, \sigma_{\Delta \log C_{t+1}}^2), \quad \text{with} \quad \sigma_{\Delta \log C_{t+1}}^2 = \alpha_0 + \alpha_1 \sigma_{\Delta \log C_{t}}^2 + \alpha_2 \varepsilon_{\Delta \log C_{t}}^2.
\]
We use the long sample 1948Q1-2016Q4 to fit the GARCH process and obtain estimates for consumption growth volatility. Panel C of Table 5 reports the summary statistics for the quarterly period 1964Q1-2016Q4.

### 4.2 Labor market search frictions and future excess bond returns

In this section, we show that changes in labor market search frictions predict future excess bond returns. We run the following predictive regression for monthly observations of annual returns:
returns:

\[ r_{x_{t+1}}^{(n)} = \alpha^{(n)} + \beta^{(n)} X_t + \varepsilon_{t+1}^{(n)}. \] (22)

for predictive variables \( X_t \in \{ \Delta \log N_t, \Delta \Theta_t \} \) being aggregate employment growth and changes in labor market tightness.

Table 6 reports results for the above regression (22). We adjust standard errors using Newey-West with twelve lags to account for the overlapping windows in the regressions. Panel A reports results using aggregate employment growth as the predictive variable. The regression slope coefficients are all negative and statistically significant. The point estimates imply that, on average, a one standard deviation decrease in employment growth over the past month is associated with a 1% increase in excess returns for an equal weighted portfolio of two to five year bonds over the next year. The corresponding \( R^2 \) is 7.9%. Furthermore, the magnitude of the slope coefficient is increasing across bond maturities. The point estimates imply that, across maturities, the average increase in excess returns following a one standard deviation decrease in employment growth ranges from 0.54% for a two year bond to 1.41% for a five year bond. The corresponding \( R^2 \) range from 9.4% for the two year bond to 6.8% for the five year bond.

Panel B reports results with changes in labor market tightness as the predictive variable. The findings are broadly similar to those in Panel A. Decreases in labor market tightness are associated with increases in future excess bond returns. The regression slope coefficients are all negative and statistically significant, with the magnitude of the point estimates being increasing in the maturity of the bond. For the equal weighted bond portfolio, a one standard deviation decrease in labor market tightness is associated with an average increase of 0.54% in excess returns; the corresponding \( R^2 \) for the regression is 2.2%. Across maturities,
the average increase in excess returns following a one standard deviation decrease in labor market tightness range from 0.33% for a two year bond to 0.70% for a five year bond. The corresponding $R^2$ range between 3.6% for the two period bond and 1.6% for the five year bond.

Next, we show that our results are robust to the inclusion of other known predictive variables. We repeat our analysis from regression (22) with additional controls:

$$rx_{t+1}^{(n)} = \alpha^{(n)} + \beta^{(n)} X_t + \gamma^{(n)} Controls_t + \varepsilon_{t+1}^{(n)}. \tag{23}$$

Controls include monetary policy as measured by the Federal Funds rate (FFR); overall economic conditions as measured by the three month moving average of the Chicago Fed National Activities Index (CFNAI); CPI inflation (INF); bond supply as measured by the maturity weighted debt to GDP (MWDGDP) series from Greenwood and Vayanos (2014); the equity market dividend-price ratio (DP); the BAA-AAA credit spread (CS); as well as the Cochrane and Piazzesi (2005) factor (CP) constructed over our sample period.

Table 7 shows the results, with Panel A reporting results for $X_t$ being employment growth and Panel B reporting results for $X_t$ being equal to changes in labor market tightness. The main findings from our univariate predictive regressions continue to hold; both employment growth and changes in labor market tightness negatively predict future bond excess returns. Furthermore, the point estimates for our labor market variables remain similar in magnitude to their counterparts in the univariate regression results from Table 6.
4.3 Labor market search frictions and future growth in economic activities

In this section, we show that increases in labor market search frictions predict slowdowns in future economic activity. We begin by showing that shocks to labor market tightness are persistent. Panel A of Table 8 shows results for the predictive regression for future changes in labor market tightness:

\[ \Theta_{t+k} - \Theta_t = \alpha_{\Delta\Theta,k} + \beta_{\Delta\Theta,k} \Delta \Theta_t + \varepsilon_{\Delta\Theta,t+k}, \]

(24)

for \( k \) ranging between one and eight quarters. We see that the change in labor market tightness over the past quarter positively predicts future changes in labor market tightness for up to eight quarters. The change in future labor market tightness is hump shaped with the effect peaking around four quarters out.

Next, we investigate how changes in labor market tightness affect future economic activity using the following regression:

\[ X_{t+h} - X_t = \alpha_{\Delta X,h} + \beta_{\Delta X,h} \Delta \Theta_t + \gamma_{\Delta X,h} (X_t - X_{t-1}) + \varepsilon_{\Delta X,t+h}. \]

(25)

In particular, we consider the association between changes in labor market tightness and future employment growth \((X = \log N)\), output growth \((X = \log Y)\), consumption growth \((X = \log C)\), as well as consumption growth volatility \((X = \sigma_{\Delta \log C})\). In all cases, we included lagged changes over the past quarter.

Panel B of Table 8 reports the response in cumulative employment growth following a change in labor market tightness. An increase in labor market tightness positively predicts
employment growth. The response in employment growth is initially sluggish but is very persistent, and peaks some 6 to 7 quarters following the initial shock to labor market tightness. The corresponding response for cumulative output growth is shown in Panel C. Output positively response to an increase in labor market tightness, with the effect lasting up to 5 to 6 quarters. Panel D reports the cumulative response in consumption growth. The initial response in consumption growth to an increase is labor market tightness is also positive, but is much smoother relative to output. This initial increase in consumption subsides after 2 quarters. Panel E reports the cumulative change in consumption growth volatility. An increase in labor market tightness is associated with lower future consumption volatility, with the decline being largest for a horizon of 5 quarters. Overall, we see that a tightening of labor markets positively predicts future economic activities, which is broadly in line with our model.

5 Conclusion

We propose a model of interest rates which links bond excess returns to the real economy. The key determinant of interest rate risk in our model is the presence of labor market search frictions. We find that a change in the number of job-openings posted by firms in the current period has a long-lived effect on future hiring costs. In general equilibrium, this has a first-order effect on the distribution of consumption risk faced by the representative household. We show that the risk-premium of a long-term bond, over a holding period shorter than its maturity, is positive in this economy. Our model predicts this premium to be larger (smaller) when hiring rates and labor market tightness are lower (higher). We test our model’s predictions in US data and find support.
References


Table 1: Parameter values We simulate our model at a monthly frequency using the parameters shown in the table below.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Persistence parameter</td>
<td>$\lambda$</td>
<td>0.889</td>
</tr>
<tr>
<td>Long-run probability of $s_1$</td>
<td>$\pi_1$</td>
<td>0.2</td>
</tr>
<tr>
<td>Log-Productivity shock in state $s_1$</td>
<td>$z_1$</td>
<td>-0.025</td>
</tr>
<tr>
<td>Log-Productivity shock in state $s_2$</td>
<td>$z_2$</td>
<td>0</td>
</tr>
<tr>
<td>Time preference parameter</td>
<td>$\beta$</td>
<td>0.9985</td>
</tr>
<tr>
<td>Risk aversion</td>
<td>$\gamma$</td>
<td>10</td>
</tr>
<tr>
<td>Worker’s bargaining power</td>
<td>$\eta$</td>
<td>0.02</td>
</tr>
<tr>
<td>Vacancy creation cost</td>
<td>$\kappa$</td>
<td>1.6</td>
</tr>
<tr>
<td>Curvature of matching function</td>
<td>$\iota$</td>
<td>1.24</td>
</tr>
<tr>
<td>Exogenous separation probability</td>
<td>$\chi$</td>
<td>0.032</td>
</tr>
<tr>
<td>Unemployment benefit parameter</td>
<td>$b$</td>
<td>0.88</td>
</tr>
</tbody>
</table>
Table 2: Labor market and asset pricing moments

Our model is simulated at monthly frequency. The unemployment data is from the Current Population Survey (CPS) and consumption data is Real Personal Consumption Expenditures from the Bureau of Economic Analysis (BEA); both these are over the period 1964 – 2016. Market tightness is from the JOLTS series between 2001 – 2016. Real bond returns are computed from the TIPS Yield Curve constructed by Gurkaynak, Sack, and Wright (GSW) over the period 1999-2016. Unemployment, labor market tightness, and consumption are hp filtered with smoothing parameter 1600.

<table>
<thead>
<tr>
<th>Moment</th>
<th>Data</th>
<th>Model</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Labor market moments</strong>:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unemployment: Mean (%)</td>
<td>5.60</td>
<td>5.86</td>
</tr>
<tr>
<td>Unemployment: Volatility (%)</td>
<td>0.75</td>
<td>0.62</td>
</tr>
<tr>
<td>Tightness: Mean</td>
<td>0.54</td>
<td>0.84</td>
</tr>
<tr>
<td>Tightness: Volatility</td>
<td>0.10</td>
<td>0.13</td>
</tr>
<tr>
<td>Correlation (unemployment, market tightness)</td>
<td>-0.89</td>
<td>-0.85</td>
</tr>
<tr>
<td>Job finding rate</td>
<td>0.45</td>
<td>0.52</td>
</tr>
<tr>
<td>$\sigma(Wage)/\sigma(Output)$</td>
<td>0.44</td>
<td>0.33</td>
</tr>
</tbody>
</table>

| Consumption growth (monthly):   |      |       |
| Volatility (%)                  | 0.80 | 0.95  |
| Autocorrelation                 | 0.04 | 0.24  |

| 1 month risk-free rate (annualized): |      |       |
| Mean (%)                           | 1.23 | 1.30  |
| Volatility (%)                     | 1.78 | 2.50  |

Table 3: Average risk premium of long-term bonds in the data and in our model. $r_x^{(n)}$ is the excess return of a bond which matures in $n$ periods. The holding period of each of these bonds is one year.

<table>
<thead>
<tr>
<th>$r_x^{(n)}$</th>
<th>Data</th>
<th>Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>$r_x^{(2)}$</td>
<td>0.48</td>
<td>0.44</td>
</tr>
<tr>
<td>$r_x^{(3)}$</td>
<td>0.88</td>
<td>0.70</td>
</tr>
<tr>
<td>$r_x^{(4)}$</td>
<td>1.21</td>
<td>0.78</td>
</tr>
<tr>
<td>$r_x^{(5)}$</td>
<td>1.33</td>
<td>0.80</td>
</tr>
</tbody>
</table>
Table 4: Inverse relationship between bond excess returns and change in tightness

The last 4 rows in the table are model-implied excess bond returns for a holding period of one year in percent. Numbers in parenthesis indicate the maturity of the bond in years.

<table>
<thead>
<tr>
<th></th>
<th>Unconditional</th>
<th>s = 1</th>
<th>s = 2</th>
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</thead>
<tbody>
<tr>
<td><strong>Labor market tightness:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\theta$</td>
<td>0.84</td>
<td>0.60</td>
<td>0.90</td>
</tr>
<tr>
<td><strong>Excess returns:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$rx^{(2)}$</td>
<td>0.44</td>
<td>0.92</td>
<td>0.33</td>
</tr>
<tr>
<td>$rx^{(3)}$</td>
<td>0.70</td>
<td>1.47</td>
<td>0.51</td>
</tr>
<tr>
<td>$rx^{(4)}$</td>
<td>0.78</td>
<td>1.63</td>
<td>0.57</td>
</tr>
<tr>
<td>$rx^{(5)}$</td>
<td>0.80</td>
<td>1.68</td>
<td>0.58</td>
</tr>
</tbody>
</table>
Table 5: Summary statistics. Panels A and B report monthly variables used in our return predictability regressions. All variables are for the period 1964m1-2016m12 except for the Chicago Fed National Activities Index (1967m5 onwards), and the maturity weighted debt to GDP series (available up until 2007m12). Panel C reports quarterly variables used in our macroeconomic regressions. All series are for the period 1964Q1-2016Q4.

### A. Macroeconomic variables, monthly frequency

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Mean</th>
<th>StDev</th>
<th>$\Delta \Theta$</th>
<th>$\Delta \log N$</th>
<th>CFNAI</th>
<th>INF</th>
<th>FFR</th>
<th>MWDGDP</th>
<th>DP</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\Delta \Theta$</td>
<td>636</td>
<td>0.0004</td>
<td>0.033</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\Delta \log N$</td>
<td>636</td>
<td>0.0015</td>
<td>0.0021</td>
<td>0.35</td>
<td></td>
<td></td>
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<tr>
<td>CFNAI</td>
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<td>-0.005</td>
<td>0.882</td>
<td>0.40</td>
<td>0.82</td>
<td></td>
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<tr>
<td>INF</td>
<td>636</td>
<td>0.0003</td>
<td>0.003</td>
<td>-0.09</td>
<td>0.09</td>
<td>0.09</td>
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</tr>
<tr>
<td>FFR</td>
<td>636</td>
<td>5.351</td>
<td>3.746</td>
<td>-0.16</td>
<td>0.05</td>
<td>0.04</td>
<td>0.54</td>
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<tr>
<td>MWDGDP</td>
<td>528</td>
<td>2.275</td>
<td>1.114</td>
<td>0.05</td>
<td>-0.04</td>
<td>-0.03</td>
<td>-0.38</td>
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<tr>
<td>DP</td>
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<td>2.929</td>
<td>1.847</td>
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<td>0.06</td>
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<td>0.27</td>
<td>0.41</td>
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<td>CS</td>
<td>636</td>
<td>1.043</td>
<td>0.455</td>
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<td>-0.48</td>
<td>-0.52</td>
<td>0.03</td>
<td>0.25</td>
<td>-0.20</td>
<td>0.24</td>
</tr>
</tbody>
</table>

### B. Bond returns, monthly observations of annual returns

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Mean</th>
<th>StDev</th>
<th>S.R.</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\overline{r_T}$</td>
<td>636</td>
<td>0.97</td>
<td>3.64</td>
<td>0.27</td>
</tr>
<tr>
<td>$r_T^{(2)}$</td>
<td>636</td>
<td>0.48</td>
<td>1.72</td>
<td>0.28</td>
</tr>
<tr>
<td>$r_T^{(3)}$</td>
<td>636</td>
<td>0.88</td>
<td>3.15</td>
<td>0.28</td>
</tr>
<tr>
<td>$r_T^{(4)}$</td>
<td>636</td>
<td>1.21</td>
<td>4.39</td>
<td>0.28</td>
</tr>
<tr>
<td>$r_T^{(5)}$</td>
<td>636</td>
<td>1.33</td>
<td>5.43</td>
<td>0.24</td>
</tr>
<tr>
<td>$CP$</td>
<td>636</td>
<td>0.97</td>
<td>1.75</td>
<td></td>
</tr>
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</table>

### C. Macroeconomic variables, quarterly frequency

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Mean</th>
<th>StDev</th>
<th>$\Delta \Theta$</th>
<th>$\Delta \log N$</th>
<th>$\Delta \log Y$</th>
<th>$\Delta \log C$</th>
<th>$\Delta \sigma_{\Delta \log C}$</th>
<th>$\overline{\Delta \sigma_{\Delta \log C}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\Delta \Theta$</td>
<td>211</td>
<td>0.0011</td>
<td>0.063</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\Delta \log N$</td>
<td>211</td>
<td>0.0044</td>
<td>0.0055</td>
<td>0.61</td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\Delta \log Y$</td>
<td>211</td>
<td>0.0073</td>
<td>0.0082</td>
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<td>0.67</td>
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<tr>
<td>$\Delta \log C$</td>
<td>211</td>
<td>0.0079</td>
<td>0.0067</td>
<td>0.58</td>
<td>0.54</td>
<td>0.67</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\Delta \sigma_{\Delta \log C}$</td>
<td>211</td>
<td>-0.0015</td>
<td>0.165</td>
<td>-0.01</td>
<td>-0.13</td>
<td>-0.05</td>
<td>0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 6: Predicting bond market excess returns. This table reports results for the univariate return predictability regression \((22)\). Panel A reports results with aggregate employment growth as the predictive variable. Panel B reports results with changes in labor market tightness as the predictive variable. Observations are monthly observations of annual returns for the periods 1964m1-2016m12. Parenthesis enclose Newey-West t-statistics computed with 12 lags.

<table>
<thead>
<tr>
<th></th>
<th>(r_{x_{t+1}})</th>
<th>(r_{x_{t+1}^{(2)}})</th>
<th>(r_{x_{t+1}^{(3)}})</th>
<th>(r_{x_{t+1}^{(4)}})</th>
<th>(r_{x_{t+1}^{(5)}})</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A. Results for (\Delta \log N_t)</strong></td>
<td>(\alpha)</td>
<td>1.677***</td>
<td>0.837***</td>
<td>1.524***</td>
<td>2.038***</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(3.44)</td>
<td>(3.65)</td>
<td>(3.59)</td>
<td>(3.47)</td>
</tr>
<tr>
<td></td>
<td>(\beta)</td>
<td>-476.7**</td>
<td>-245.5**</td>
<td>-437.6**</td>
<td>-561.4**</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(-2.99)</td>
<td>(-3.05)</td>
<td>(-3.08)</td>
<td>(-2.96)</td>
</tr>
<tr>
<td><strong>R^2</strong></td>
<td></td>
<td>.079</td>
<td>.094</td>
<td>.088</td>
<td>.075</td>
</tr>
</tbody>
</table>

| **B. Results for \(\Delta \Theta_t\)** | \(\alpha\) | 0.980* | 0.478* | 0.885* | 1.216* | 1.339* |
|                  |  | (2.29) | (2.38) | (2.40) | (2.36) | (2.11) |
|                  | \(\beta\) | -16.32* | -9.835** | -15.59* | -18.81* | -21.03* |
|                  |  | (-2.25) | (-2.80) | (-2.44) | (-2.18) | (-2.00) |
| **R^2**          |  | 0.022  | 0.036  | 0.027  | 0.02   | 0.016  |

\(+ p < 0.10, * p < 0.05, ** p < 0.01, *** p < 0.001\)
Table 7: Predicting bond market excess returns: robustness. This table reports results for the multivariate return predictability regression (23). Panel A reports results for employment growth. Panel B reports results for changes in labor market tightness. Observations are monthly observations of annual returns for the periods 1967m5-2007m12. Parenthesis enclose Newey-West t-statistics computed with 12 lags.

<table>
<thead>
<tr>
<th></th>
<th>A. Results for $X_t = \Delta \log N_t$</th>
<th>B. Results for $X_t = \Delta \Theta_t$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$r\bar{x}_{t+1}$</td>
<td>$r\bar{x}_{t+1}^{(2)}$</td>
</tr>
<tr>
<td>$X_t$</td>
<td>-350.1*</td>
<td>-155.7*</td>
</tr>
<tr>
<td></td>
<td>(-2.45)</td>
<td>(-2.34)</td>
</tr>
<tr>
<td>$FFR_t$</td>
<td>0.338*</td>
<td>0.194**</td>
</tr>
<tr>
<td></td>
<td>(2.45)</td>
<td>(2.90)</td>
</tr>
<tr>
<td>$CFNAI_t$</td>
<td>-0.297</td>
<td>-0.219</td>
</tr>
<tr>
<td></td>
<td>(-0.54)</td>
<td>(-0.80)</td>
</tr>
<tr>
<td>$INF_t$</td>
<td>-175.4+</td>
<td>-84.31+</td>
</tr>
<tr>
<td></td>
<td>(-1.87)</td>
<td>(-1.87)</td>
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<tr>
<td>$MWDGDP_t$</td>
<td>0.0464</td>
<td>0.104</td>
</tr>
<tr>
<td></td>
<td>(0.15)</td>
<td>(0.70)</td>
</tr>
<tr>
<td>$DP_t$</td>
<td>-0.200*</td>
<td>-0.111*</td>
</tr>
<tr>
<td></td>
<td>(-2.21)</td>
<td>(-2.53)</td>
</tr>
<tr>
<td>$CS_t$</td>
<td>-1.326</td>
<td>-0.316</td>
</tr>
<tr>
<td></td>
<td>(-1.05)</td>
<td>(-0.49)</td>
</tr>
<tr>
<td>$CP_t$</td>
<td>1.100***</td>
<td>0.446***</td>
</tr>
<tr>
<td></td>
<td>(5.38)</td>
<td>(5.08)</td>
</tr>
<tr>
<td>$Const$</td>
<td>0.610</td>
<td>-0.229</td>
</tr>
<tr>
<td></td>
<td>(0.40)</td>
<td>(0.30)</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.330</td>
<td>0.331</td>
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</tbody>
</table>

$^+p < 0.10, ^*p < 0.05, ^{**}p < 0.01, ^{***}p < 0.001$
Table 8: Predicting cumulative changes in macroeconomic quantities with changes in labor market tightness. Panel A reports results for the labor market tightness forecasting regression (24). Panels B through E report results for the forecasting regression (25) for cumulative growth in employment, output, consumption, and consumption growth volatility, respectively. Observations are at a quarterly frequency for the period 1964-2016. Parenthesis enclose Newey-West t-statistics computed with four lags.

<table>
<thead>
<tr>
<th>Quarters ahead k</th>
<th>k = 1</th>
<th>k = 2</th>
<th>k = 3</th>
<th>k = 4</th>
<th>k = 5</th>
<th>k = 6</th>
<th>k = 7</th>
<th>k = 8</th>
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<tr>
<td>A. Labor market tightness</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\beta_{\Delta \Theta}$</td>
<td>0.513***</td>
<td>0.894***</td>
<td>1.186***</td>
<td>1.287***</td>
<td>1.236***</td>
<td>1.148***</td>
<td>0.978**</td>
<td>0.727+</td>
</tr>
<tr>
<td>(8.71)</td>
<td>(8.37)</td>
<td>(7.62)</td>
<td>(6.63)</td>
<td>(5.45)</td>
<td>(4.08)</td>
<td>(2.98)</td>
<td>(1.91)</td>
<td></td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.264</td>
<td>0.265</td>
<td>0.243</td>
<td>0.181</td>
<td>0.121</td>
<td>0.082</td>
<td>0.05</td>
<td>0.025</td>
</tr>
<tr>
<td>B. Employment</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\beta_{\Delta N}$</td>
<td>0.0272***</td>
<td>0.0494***</td>
<td>0.0718***</td>
<td>0.0917***</td>
<td>0.103***</td>
<td>0.110**</td>
<td>0.110**</td>
<td>0.103*</td>
</tr>
<tr>
<td>(6.07)</td>
<td>(4.69)</td>
<td>(4.63)</td>
<td>(4.29)</td>
<td>(3.68)</td>
<td>(3.27)</td>
<td>(2.90)</td>
<td>(2.34)</td>
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</tr>
<tr>
<td>$R^2$</td>
<td>0.702</td>
<td>0.619</td>
<td>0.538</td>
<td>0.452</td>
<td>0.373</td>
<td>0.313</td>
<td>0.256</td>
<td>0.20</td>
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<tr>
<td>C. Output</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\beta_{\Delta Y}$</td>
<td>0.0529***</td>
<td>0.0791**</td>
<td>0.0931***</td>
<td>0.0824*</td>
<td>0.0767*</td>
<td>0.0724+</td>
<td>0.0652</td>
<td>0.0454</td>
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<tr>
<td>(3.53)</td>
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<td>(3.68)</td>
<td>(2.27)</td>
<td>(1.99)</td>
<td>(1.75)</td>
<td>(1.44)</td>
<td>(0.91)</td>
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<tr>
<td>$R^2$</td>
<td>0.214</td>
<td>0.224</td>
<td>0.178</td>
<td>0.132</td>
<td>0.086</td>
<td>0.065</td>
<td>0.043</td>
<td>0.023</td>
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<td>D. Consumption</td>
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</tr>
<tr>
<td>$\beta_{\Delta C}$</td>
<td>0.0195*</td>
<td>0.0220+</td>
<td>0.0114</td>
<td>-0.00468</td>
<td>-0.0201</td>
<td>-0.0397</td>
<td>-0.0652+</td>
<td>-0.0873*</td>
</tr>
<tr>
<td>(2.48)</td>
<td>(1.75)</td>
<td>(0.66)</td>
<td>(-0.20)</td>
<td>(-0.69)</td>
<td>(-1.17)</td>
<td>(-1.77)</td>
<td>(-2.14)</td>
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<tr>
<td>$R^2$</td>
<td>0.129</td>
<td>0.161</td>
<td>0.196</td>
<td>0.155</td>
<td>0.13</td>
<td>0.123</td>
<td>0.105</td>
<td>0.089</td>
</tr>
<tr>
<td>E. Consumption growth volatility</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\beta_{\Delta \sigma_{\Delta \log C}}$</td>
<td>-0.00379</td>
<td>-0.00645+</td>
<td>-0.00692+</td>
<td>-0.00824**</td>
<td>-0.00877**</td>
<td>-0.00709*</td>
<td>-0.00731*</td>
<td>-0.00607+</td>
</tr>
<tr>
<td>(-1.24)</td>
<td>(-1.69)</td>
<td>(-1.89)</td>
<td>(-2.61)</td>
<td>(-2.88)</td>
<td>(-2.43)</td>
<td>(-2.33)</td>
<td>(-1.76)</td>
<td></td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.044</td>
<td>0.078</td>
<td>0.07</td>
<td>0.074</td>
<td>0.088</td>
<td>0.066</td>
<td>0.078</td>
<td>0.064</td>
</tr>
</tbody>
</table>

$^+$ p < 0.10, * p < 0.05, ** p < 0.01, *** p < 0.001
Figure 1: Business cycle variation of the vacancy posting rate, defined as the ratio of vacancies posted by firms to the number of employed workers, in the US.
Figure 2: Policies: Panels A through F show the number of vacancies posted by the representative firm, next period’s employment level, labor market tightness, the job-finding probability of a job-seeker, the job-filling probability of a firm, and the wage of a worker, respectively as a function of the size of the employed population. $s = 1$ ($s = 2$) refer to states with lower (higher) productivity.
Figure 3: Intuition for positive bond risk premium: Panels A through C represent the 7 out of the 2^6 most probable paths. The initial value of $N$ is the mean value of this variable for the state $s_2$. Each point corresponds to a single path; these paths are differentiated by the timing of the transition from $s_2$ to the low productivity state $s_1$. The last point ($t_{\text{switch}} > 6$) represents the path in which there are no transitions over the 6-month holding period of the bond. Panel B shows the probabilities of each of these 7 paths. Panel C shows the (demeaned) values of realized marginal utilities and the expected marginal utilities relevant to compute the bond’s risk premium.

Figure 4: Intuition for expected growth of marginal utility: Panel A shows the expected growth in marginal utility as a function of the level of employment ($N$) over a 12 month horizon. Panels B and C show the mean and volatility of consumption growth over the same horizon.
Figure 5: Risk premium of a 2 year bond over a 1 year holding period: Panel A shows that the risk premium of the bond is higher in the low-productivity state ($s = 1$) compared to the high productivity state ($s = 2$). Panel B shows the volatility of the one-year ahead pricing kernel, and panel C shows the volatility of the holding-period return of the bond.
Figure 6: Change in labor market tightness and employment growth, 1964-2016. Panel A plots month-to-month changes in labor market tightness. Panel B plots month-on-month aggregate employment growth. Shaded bands denote NBER recessions.
Appendix

A Proofs

A.1 Proof of the wage rule (14)

The Nash bargaining rule implies that $\eta\tilde{F}_t = (1-\eta)(J_{e,t} - J_{u,t})$ at all times. After substituting value expressions (9), (12), and (13) into the Nash bargaining rule, we obtain

$$w_t = \eta + (1-\eta)b + \eta f(\Theta_t)\mathbb{E}_t\left[M_{t,t+1}\tilde{F}_{t+1}\right]. \quad (A.1)$$

Next, the complementary slackness condition for vacancy posting (10) implies $\kappa(s_t)\Theta_t = \Theta_t g(\Theta_t)\mathbb{E}_t\left[M_{t,t+1}\tilde{F}_{t+1}\right] = f(\Theta_t)\mathbb{E}_t\left[M_{t,t+1}\tilde{F}_{t+1}\right]$. Substituting this expression into (A.1) yields the wage equation (14).

B Data

Our list of data sources are:

- Bond return data: Fama-Bliss Discount Bonds monthly series; downloaded from CRSP.
- Job vacancies: composite Help Wanted Index from Barnichon (2010); downloaded from Regis Barnichon’s website.
- Unemployment rate: seasonally adjusted civilian unemployment rate (UNRATE) series; downloaded from FRED.
- Aggregate employment: seasonally adjusted total nonfarm payroll (PAYEMS) series; downloaded from FRED.
- Economic activities index: three monthly moving average of the Chicago Fed National Activities Index (CFNAIMA3); downloaded from FRED.
- Inflation: inflation constructed from the Consumer Price Index (CPIAUCSL) series; downloaded from FRED.
- Monetary policy: effective Federal Funds Rate series (FEDFUNDS); downloaded from FRED.
• Bond supply: maturity weighted debt to GDP series taken from the data appendix of Greenwood and Vayanos (2014).

• Equity market risk premium: dividend to price ratio of the aggregate stock market; constructed using CRSP aggregate returns data.

• Credit spread: the BAA - AAA credit spread; downloaded from FRED.

• Output: seasonally adjusted real GDP series (GDPC1); downloaded from FRED.

• Consumption: seasonally adjusted real personal consumption expenditures series (PCECC96); downloaded from FRED.