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# Labor market dynamics, endogenous growth, and asset prices

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## HIGHLIGHTS

- We introduce endogenous labor decisions into the Kung and Schmid (2015) economy.
- Moreover, two variants of wage rigidities are added.
- Pro-cyclical labor generates a rise in the equity risk premium of 250 basis points.
- Wage rigidities produce sufficiently volatile labor hours and smooth wages.

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## ABSTRACT

We extend the endogenous growth model of Kung and Schmid (2015) by adding endogenous labor dynamics and two variants of wage rigidities. This leads to an increase of 250–350 basis points in the risk premia, depending on the model specification. Additionally, it brings labor market quantities much closer to their empirical counterparts. In particular, wage rigidities generate an increase of around 60–250 basis points in labor growth volatility, which depends on how wage rigidities are modeled.



## 1. Introduction

In this study we present an extension of a key macro-finance model which links endogenous growth theory to asset pricing. The leading literature in this field either accounts for endogenous capital accumulation or endogenous labor supply, but not for both. In the economy of Kung and Schmid (2015), which we use as a benchmark, labor supply is inelastic (i.e. fixed). On the other hand, Croce et al. (2013) do not utilize physical capital as a production factor.[2,3]

We bridge this gap by adding endogenous labor supply and wage rigidities to the Kung and Schmid (2015) model (hereinafter 'KS'). Labor market dynamics have been shown to be an important driver of business cycles. Particularly, both empirical and theoretical studies emphasize the importance

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2 Recent contributions that only consider either endogenous capital or endogenous labor supply include Akcigit and Kerr (2012); Gârleanu et al. (2012); Bena et al. (forthcoming); Jinnai (2015).

3 An exception is the New Keynesian model of Kung (2015) where both capital and labor decisions are endogenized. However, his setting – aimed at capturing the link between monetary policy and endogenous growth – cannot be directly compared to ours.

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of wage rigidities in explaining labor growth volatility, wage dynamics, and asset prices (Campbell and Kamlani, 1997; Agell and Lundborg, 2003; Hall, 2005; Blanchard and Galí, 2007; Merz and Yashiv, 2007; Smets and Wouters, 2007; Uhlig, 2007; Belo et al., 2014; Favilukis and Lin, 2016). In this respect, our work is closely related to Favilukis and Lin (2016) who introduce sticky wages into a production economy in order to explain several features of financial data. In their setting, the introduction of wage rigidities makes wages less pro-cyclical, profits more volatile and dividends highly pro-cyclical. If coupled with several other frictions and shocks, the model produces relatively smooth wages, a high equity premium, and it can account for 75% of the equity return volatility. However, similarly to KS, labor supply decisions are not endogenized.

We find that the inclusion of endogenous labor decisions in KS leads to higher aggregate risk. The reason being that households decide to work more in response to productivity shocks to fully exploit the boost in innovation intensities. As a result, labor becomes highly pro-cyclical leading to a rise of about 250 basis points (bps) in the risk premia.[4]

By introducing wage rigidities in the spirit of Uhlig (2007), our model produces a further increase in the risk premia (around 25 bps) and brings labor market quantities – including labor and wage volatility – closer to their empirical counterparts. This is due to labor (wages) becoming more (less) pro-cyclical when wage rigidities are accounted for.[5] In order to shed robustness on the effect of wage rigidities, we additionally model wage rigidities differently. Specifically, following Schmitt-Grohe and Uribe (2006), we introduce Calvo-type wage stickiness. In this setting, the aforementioned effects are moderately amplified.

## 2. Model

This section extends KS by accounting for endogenous labor supply and wage rigidities. In Section 2.1 we review KS. Section 2.2 introduces the aforementioned extensions.

### 2.1. Benchmark model

Kung and Schmid (2015) develop a stochastic version of the endogenous growth model by Romer (1990), where the household has recursive preferences and capital investment is subject to convex adjustment costs.

**Representative household**. The representative household has Epstein and Zin (1989) preferences over the utility flow $u_t$:

$$U_t = \left[ (1-\beta) u_t^{1-\frac{1}{\psi}} + \beta \left( \mathbb{E}_t [U_{t+1}^{1-\gamma}] \right)^{\frac{1-1/\psi}{1-\gamma}} \right]^{\frac{1}{1-1/\psi}}, \tag{1}$$

where $\gamma$ is relative risk aversion, $\psi$ determines the elasticity of intertemporal substitution, and $\beta$ is the time discount factor. The utility flow is identical to consumption:

$$u_t = C_t. \tag{2}$$

The budget constraint of the household reads:

$$C_t = W_t L_t + D_{a,t}, \tag{3}$$

where $W_t$ denotes wages, $L_t$ is the amount of labor supplied by the household, and $D_{a,t}$ is aggregate dividends. Since there is no disutility from labor, the household supplies its total time endowment each period. Hence, $L_t \equiv 1$ in equilibrium. The household's stochastic discount factor (SDF) is:

$$\mathbb{M}_{t,t+1} = \beta \left( \frac{u_{t+1}}{u_t} \right)^{-\frac{1}{\psi}} \left( \frac{U_{t+1}}{\mathbb{E}_t [U_{t+1}^{1-\gamma}]^{\frac{1}{1-\gamma}}} \right)^{\frac{1}{\psi}-\gamma}. \tag{4}$$

**Final good sector**. Production output of the representative final good sector firm is given by:

$$Y_t = (K_t^{\alpha} (A_t L_t)^{1-\alpha})^{1-\xi} G_t^{\xi}, \qquad G_t = \left[ \int_0^{N_t} X_{i,t}^{\nu} \, di \right]^{\frac{1}{\nu}}. \tag{5}$$

The capital share, the share of intermediate goods and the elasticity of substitution between any two intermediate goods in the intermediate goods bundle $G_t$ are denoted by $\alpha$, $\xi$ and $\nu$, respectively. The total number of intermediate goods or patents in the economy is $N_t$. The stochastic process $A_t$ introduces exogenous stochastic productivity shocks to the model with dynamics:

$$A_t = e^{a_t}, \quad a_t = \rho_a \cdot a_{t-1} + \varepsilon_{a,t}, \tag{6}$$

where $\rho_a$ determines the persistence of these shocks and $\varepsilon_{a,t} \sim \mathcal{N}(0, \sigma_a)$. The final good firm maximizes its shareholder value by optimally choosing capital investment $I_t$, labor $L_t$, next period's capital $K_{t+1}$ and the demand for intermediate good $i$, $X_{i,t}$:

$$\max_{\{I_t, L_t, K_{t+1}, X_{i,t}\}_{t \geq 0, i \in [0, N_t]}} \mathbb{E}_0 \left[ \sum_{t=0}^{\infty} \mathbb{M}_{0,t} D_t \right], \tag{7}$$

subject to the final good firm's dividends' definition and the capital accumulation equation:

$$D_t = Y_t - I_t - W_t L_t - \int_0^{N_t} P_{i,t} X_{i,t} \, di, \tag{8}$$

$$K_{t+1} = (1-\delta) K_t + \Lambda \left( \frac{I_t}{K_t} \right) K_t, \tag{9}$$

where $P_{i,t}$ is the price of intermediate good $i$, $\delta$ is the capital depreciation rate and $\Lambda \left( \frac{I_t}{K_t} \right) = \frac{\alpha_1}{1-\frac{1}{\zeta}} \left( \frac{I_t}{K_t} \right)^{1-\frac{1}{\zeta}} + \alpha_2$ is the adjustment cost function transforming investment in new capital as in Jermann (1998), where the constants $\alpha_1$ and $\alpha_2$ are chosen so that there are no adjustment costs in the deterministic steady state. The resulting equilibrium conditions are as follows:

$$1 = \mathbb{E}_t \left[ \mathbb{M}_{t,t+1} \Lambda' \left( \frac{I_t}{K_t} \right) \left\{ \frac{(1-\xi)\alpha Y_{t+1} - I_{t+1}}{K_{t+1}} + \frac{\Lambda \left( \frac{I_{t+1}}{K_{t+1}} \right) + 1 - \delta}{\Lambda' \left( \frac{I_{t+1}}{K_{t+1}} \right)} \right\} \right], \tag{10}$$

$$W_t = \frac{(1-\xi)(1-\alpha) Y_t}{L_t}, \tag{11}$$

$$X_{i,t}(P_{i,t}) = \left( \frac{\xi Y_t}{P_{i,t}} \right)^{\frac{1}{1-\nu}} G_t^{\frac{\nu}{\nu-1}}. \tag{12}$$

**Intermediate goods sector**. Each intermediate good $i \in [0, N_t]$ is produced by a monopolistically competitive firm maximizing its profits:

$$\max_{\{P_{i,t}\}} \Pi_{i,t} = \max_{\{P_{i,t}\}} \left\{ P_{i,t} X_{i,t}(P_{i,t}) - X_{i,t}(P_{i,t}) \right\}. \tag{13}$$

[4] Note that this effect would be reversed in a model with exogenous growth.

[5] As in Favilukis and Lin (2016), the inclusion of wage rigidities allows the model to generate smoother wages. Still, as in related production economy models (Jermann, 1998; Boldrin et al., 2001; Kung and Schmid, 2015), equity volatility is relatively low. This finding is at odds with Favilukis and Lin (2016) who explain up to 75% of the empirically observed equity return volatility. However, there are several differences between their setting and ours, in particular regarding the structure of wage rigidities and of financial leverage.