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Asset Prices, Growth and Wage inertia*

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Abstract

Traditionally, production based asset pricing literature have largely assumed a frictionless labor market where wages equal marginal productivity of labor. Such a labor market assumption of flexible wages makes dividend acyclical or countercylical contradicting empirical evidence. Towards this end, this paper uses a production economy where growth is endogenously determined by innovation to examine the implications of wage inertia on macroeconomic aggregates and asset prices. We incorporate and compare between different kinds of wage inertia such as wage stickiness with endogenous labor supply, search and matching models with Nash and with alternative offer bargaining. Our simulations show that a) wage inertia determined in an alternative offer bargaining framework brings labor market and asset pricing moments closer to the data; b) the impulse response of dividends is larger – and closer to the data - under alternative offer bargaining compared to the other models since wages rise the least, as labor, vacancies and unemployment are more responsive following a positive productivity shock.

Keywords: Endogenous growth, Wage Inertia, Wage rigidity, Nash bargaining, Alternating offer bargaining, Unemployment, Long run risk, Asset pricing

JEL classification: G12, J64, O30, O41, J31, J50

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1 Introduction

The paradigm shift from consumption based asset pricing models to the more recent production based asset pricing models pioneered by Cochrane (1991) and Jermann (1998) has mostly ignored the dynamics of the labour market. Recent papers by Tallarini (2000), Kaltenbrunner and Lochstoer (2010) and Croce (2014) have used non trivial production sectors to explain asset pricing moments, but have assumed a frictionless labour market so wage equals marginal productivity of labour. This could have far fetching implications on the asset pricing as dynamics of wage form an integral part of the value of the firm. For example, in standard frictionless labour models, dividends equal profits minus investment, and profits equal output minus wages. Since wages equal the marginal product of labour, it is procyclical as output. This makes profits smoother and dividends acyclical or countercyclical contradicting empirical evidence[1].

The few studies which have integrated the more realistic wage dynamics in the asset pricing models have mostly assumed wage-setting subject to nominal rigidities. Li and Palomino (2014) belong to this category in the labour-asset pricing literature. They show that in the Kaltenbrunner and Lochstoer (2010) model of permanent and transitory technology shocks, the absence or presence of nominal rigidities – nominal rigidities are modeled following the Calvo (1983) staggered price and wage setting – can determine whether the risk premium is negative or positive, respectively. Though the model captures key macroeconomic moments and the Sharpe ratio of stock returns, equity premium falls short of its empirical counterpart. Favilukis and Lin (2016) consider a different variant of wage modeling in terms of infrequent wage resetting where average wage paid by firms is taken to be equal to the weighted average of historical spot wages. On account of this wage modeling, the average wage becomes smoother than the marginal product of labour. They find that the profit and dividend behavior look very much like the data. However, the volatility of equity and the value premium fall short of the data.

While Li and Palomino (2014) and Favilukis and Lin (2016) consider labour supply as exogenous, a recent paper by Donadelli and Grüning (2016) departs from this framework by considering endogenous labour supply in addition to wage rigidities. Donadelli and Grüning (2016) find that including endogenous labour supply leads to higher aggregate risk as labour becomes highly procyclical leading to a rise of about 250 basis points in the risk premia. How-

[1]Please refer to Favilukis and Lin (2016) among others.

ever, these models have been criticised for simply assuming wage inertia especially since wage inertia itself is what drives the results.

Instead of simply assuming wage inertia, search and matching labour market models derive wage inertia as an equilibrium outcome. As part of a recent emerging literature on asset pricing, Petrosky-Nadeau et al. (2018) integrate the standard Diamond-Mortensen-Pissarides (DMP) labour search and matching model to the asset pricing framework to avoid the common pitfall of countercyclical dividends in standard asset pricing models[2]. They use the labour search and matching framework to delink wages from the marginal product of labour to explain why wages fall during bad times, but not as much as the fall in output. This causes profits to drop disproportionately and makes the dividends more procyclical leading to higher equity premium. However, the risk free rate is higher than in the data and volatility of interest rate falls short of the data. Kuehn et al. (2017) develop a partial equilibrium labour search model and show that labour search frictions are vital in determining cross-section equity returns. For tractability, they use a partial equilibrium asset pricing model focusing on a labour market model with labour as the only input for production, and its implications on stock returns. They do not model endogenous labour supply decisions from households but instead consider the pricing kernals as exogenous. However, an endogenous pricing kernel would capture preferences concerning uncertainty about long-run growth prospects as mentioned by Croce (2014) and Kung and Schmid (2015). With such preferences, households fear that persistent downturns in economic growth are accompanied by low asset valuations and command high-risk premia in asset markets, explaining the equity premium puzzle. Apart from pricing kernal, partial equilibrium labour asset pricing model would ignore the contribution of the returns on physical capital on equity premium. Hence, a general equilibrium production based asset pricing model with both capital and labour can provide a unified framework to explain both asset pricing and macroeconomic dynamics. In this context, Branger et al. (2016) consider the asset pricing implications of DMP search and matching model in an endogenous growth model of Kung and Schmid (2015). However, they assume vacancy posting cost to be fixed and equal to one and their model is able to explain only 60 percent of the equity premium in the data. In addition, DMP search models are subject to Shimer (2005)'s critique that higher labour productivity

[2]The standard search and matching model in the labour market was developed by Diamond (1982), Mortensen (1982) and Pissarides (1985)

will have small effects on unemployment, vacancy and job finding rates since the increase in productivity is absorbed by higher wages arising from the increase in workers' threat point in wage bargaining as unemployment duration decreases with lower unemployment and higher vacancy rates.

We examine the implications on asset prices and macroeconomic aggregates of incorporating labour market frictions in a production-based, asset-pricing, general equilibrium framework of Kung and Schmid (2015). Through endogenous creation of new patented technologies through R&D, Kung and Schmid (2015) model small but persistent component in the growth rate of productivity (long run productivity shocks). Hence, they provide production-based micro foundations for long run risks proposed by Bansal and Yaron (2004). While other papers like Gârleanu et al. (2009) and Gârleanu et al. (2012) examine the link between technological growth and asset prices, the arrival of new technologies is assumed to be exogenous. In comparison, Kung and Schmid (2015) examine the asset pricing and growth implications of the endogenous creation of new technologies through R&D. Kung and Schmid (2015) is the most recent effort at studying asset pricing puzzles within a DSGE framework. Another advantage of Kung and Schmid (2015) model lies in its ability to jointly capturing the dynamics of aggregate quantities and asset markets.

In this paper, we study the labour market implications in the production based asset pricing economy of Kung and Schmid (2015). Our paper differs from other labour asset pricing papers on account of the specification of the search and matching framework of the labour market. We pursue a variant of Christiano et al. (2016) approach to labour market in contrast to den Haan et al. (2000). Instead of simply assuming wage inertia, Christiano et al. (2016) derives wage inertia as an equilibrium outcome. Christiano et al. (2016) performed the novel idea of integrating search and matching model labour market into a New Keynesian economic framework. They capture the key empirical properties of labour market variables like job finding rate, vacancies and unemployment of United States using the alternate offer bargaining (AOB) framework. This is a significant improvement from the other new Keynesian models that build on Diamond (1982), Mortensen (1982) and Pissarides (1985) who have difficulty accounting for the volatility of labor markets (Shimer, 2005).

Our motivation for using Christiano et al. (2016) labour market specification lies with the objective of using different bargaining regimes like alternate offer sharing rule in addition to Nash sharing rule to model rent sharing between firm and its workforce to see the impact on asset prices. Christiano et al. (2016) finds that AOB framework is not subject to Shimer (2005) critique of search and matching models (unlike Nash bargaining) and makes the unemployment volatility of the model more consistent with its empirical counterparts. For comparison, we also consider labour market friction which assumes nominal wage rigidities as in Uhlig (2007) and endogenous labour supply following Donadelli and Grüning (2016), and the frictionless labour market in Kung and Schmid (2015)[3] .

We find that following a positive productivity shock, the models with wage inertia show slight improvements to the benchmark KS model compared with US data in terns of moments like proportion of standard deviation of output explained by standard deviation of dividends, correlation of dividends and output, correlation of dividend growth and output growth, equity premium, standard deviation of risk free rate. For the search and matching labour market models, the AOB shows labour market moments closer to the data than the Nash bargaining consistent with the findings of Christiano et al. (2016). However, the AOB labour market framework shows asset pricing moments including the standard deviations of the growth of dividends and the correlation between dividend and output, which are much closer to the data compared with the benchmark KS model and the other types of models of wage inertia. However, while the standard deviation of the price to dividend is underestimated in models with other types of wage inertia, it is overestimated by 78% in the AOB model compared to the data. The impulse responses show that under AOB, wages rise the least, as labour, vacancies and unemployment are more responsive following a positive productivity shock. Hence, the response of dividends is larger – and closer to the data – under AOB than the benchmark KS model or the models with other types of wage inertia.

The higher asset pricing moments in our model arise from endogenous long run risk associated with consumption in the Kung and Schmid (2015) model which is aggravated by the higher unemployment volatility in the AOB framework of Christiano et al. (2016). In the Kung and Schmid (2015) model, the long run risk is endogenously created by a persistent component of economic growth. With recursive preferences, people fear long-term low growth and economic downturn will lower asset prices, and require a higher risk premium to hold assets even with fric-

[3] Christiano et al. (2016) do not consider the impact of alternate offer bargaining on asset prices.

tionless labour markets. Incorporating search and matching labour market frictions of the AOB model into the Kung and Schmid (2015) model means economic downturns and low growth are accompanied by high unemployment. The high unemployment rate creates cash flow risk with respect to wages during economic downturn for the household. In order to smooth consumption during periods of high unemployment, household agents would require an even higher equity premium to hold assets compared to the benchmark KS model.

The paper is organised as follows: section 1 describes the benchmark KS model without labour market friction and modifications of the KS model with various types of labour market frictions; section 3 describes the calibration of the models; Sections section 4 discuss the labour market dynamics, aggregate quantity dynamics and asset pricing implications, respectively: and section 5 concludes.

2 Model

This section embeds the Kung and Schmid (2015) model with wage rigidities, Nash bargaining and alternate offer bargaining frameworks of the search and matching frictions in the labour market.

In the KS model, the labour market is perfectly competitive (i.e.wages equal marginal productivity of labour) resulting in 1) counter-factual highly pro-cyclical swings in wages, and 2) the inability of the model to capture the dynamics of dividends. Hence, we introduce labour market frictions in the model through wage rigidities (Donadelli and Grüning, 2016) and search and matching framework of labour market (Christiano et al., 2016). The search and matching labour market model includes alternate offer bargaining (henceforth AOB) and the Nash bargaining framework by Christiano et al. (2016). We compare the KS models with labour market frictions to see which of the models could better account for key properties of asset pricing and macroeconomic aggregates, including labour market variables.

2.1 Benchmark KS model without labour market frictions

Our benchmark model is the Kung and Schmid (2015) (henceforth KS) model.[4] Final goods in the economy are produced by the final goods sector using capital, labour and intermediate

[4]Benchmark model is the Kung and Schmid (2015) asset pricing model. We have made no extensions to Kung and Schmid (2015) in the benchmark model.

goods. Final goods sector receive the intermediate good input from a monopolistic competitive intermediate goods sector. There are i varieties of intermediate goods produced by the intermediate goods sector. Newer varieties of intermediate goods are developed by the research and development (R&D) sector, who sells the associated production patents to the intermediate goods sector. R&D sector driven innovation leads to a sustained growth of intermediate goods variety patents. Long run risk endogenously arises due to this sustained growth, which affects the expected consumption growth from Epstein-Zin utility preferences[5].

2.1.1 Final goods sector

The representative firm uses capital K_t, labour L_t and a composite of intermediate goods G_t in the below production function to supply final goods for consumption

$$Y_t = (K_t^{\alpha}(\Omega_t L_t)^{1-\alpha})^{1-\xi} G_t^{\xi} \tag{1}$$

G_t is the intermediate good bundle given by

$$G_t \equiv \left[\int_0^{N_t} X_{i,t}^{\frac{1}{\nu}} \, di \right]^{\nu} \tag{2}$$

where $X_{i,t}$ is intermediate good $i \in [0, N_t]$. α and ξ denote the share of capital and intermediate goods respectively in the production function. ν refers to the elasticity of substitution among i varieties of intermediate goods.

The objective of the firm is to maximise shareholder's wealth

$$\max_{\{I_t, L_t, K_{t+1}, X_{i,t}\}_{t \geq 0, i \in [0, N_t]}} E_0 \left[\sum_{t=0}^{\infty} M_t D_t \right]$$

where M_t is the stochastic discount factor and D_t is the firm's dividends. Dividend is given by output (Y_t) minus capital investment (I_t), wage expenses $(W_t L_t)$ and intermediate goods expenses where $P_{i,t}$ is the price per unit of intermediate good i.

[5]Subsection 2.1 mostly follows the presentation and notations of Kung and Schmid (2015) model in the earlier versions of their paper particularly their section on "benchmark endogenous growth model (ENDO)."

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

The evolution of capital stock is given by

$$K_{t+1} = (1-\delta)K_t + \Lambda\left(\frac{I_t}{K_t}\right) K_t \tag{3}$$

where δ denotes the depreciation rate of capital. The capital adjustment cost function $\Lambda\left(\frac{I_t}{K_t}\right)$ is given by Jermann (1998).

$$\Lambda\left(\frac{I_t}{K_t}\right) \equiv \frac{\alpha_1}{1-\frac{1}{\zeta}}\left(\frac{I_t}{K_t}\right)^{1-\frac{1}{\zeta}} + \alpha_2 \tag{4}$$

where parameter ζ refers to the elasticity of the investment rate. When $\zeta \to 0$, capital adjustment cost is infinite. On the other hand, $\zeta \to \infty$ implies frictionless adjustment. α_1 and α_2 are specified so that there are no adjustment costs in the steady state.[6]

The Lagrangian for maximizing shareholder wealth is

$$\mathcal{L} = E_0\Big[\sum_{t=0}^{\infty} M_t \Big\{Y_t - I_t - W_t L_t - \int_0^{N_t} P_{i,t} X_{i,t}\, di + q_t\Big((1-\delta)K_t + \Lambda\Big(\frac{I_t}{K_t}\Big) K_t - K_{t+1}\Big)\Big\}\Big] \tag{5}$$

The resulting first order conditions are

$$\begin{aligned}
I_t &: -1 + q_t \cdot \Lambda'\left(\frac{I_t}{K_t}\right) = 0\\
L_t &: (1-\alpha)(1-\xi)\frac{Y_t}{L_t} - W_t = 0\\
X_{i,t} &: (K_t^{\alpha}(\Omega_t L_t)^{1-\alpha})^{1-\xi}\nu\xi\left[\int_0^{N_t} X_{i,t}^{\frac{1}{\nu}}\, di\right]^{\nu\xi-1}\frac{1}{\nu}X_{i,t}^{\frac{1}{\nu}-1} - P_{i,t} = 0\\
K_{t+1} &: E_t\Big[M_{t+1}\Big\{\alpha(1-\xi)\frac{Y_{t+1}}{K_{t+1}} + q_{t+1}\Big((1-\delta) - \Lambda'\Big(\frac{I_{t+1}}{K_{t+1}}\Big)\cdot\Big(\frac{I_{t+1}}{K_{t+1}}\Big) + \Lambda\Big(\frac{I_{t+1}}{K_{t+1}}\Big)\Big)\Big\}\Big] - q_t = 0
\end{aligned}$$

$\Lambda_t \equiv \Lambda\left(\frac{I_t}{K_t}\right)$ and $\Lambda'_t \equiv \Lambda'\left(\frac{I_t}{K_t}\right)$ are defined so as to simplify the notations. This changes the

[6] In the deterministic steady state with no adjustment cost, $\Lambda\left(\frac{\bar{I}}{\bar{K}}\right) = \frac{\bar{I}}{\bar{K}}$. Using the steady state version of Equation 3 and Equation 4, we can derive $\alpha_1 = \left(\overline{\Delta N} - 1 + \delta\right)^{\frac{1}{\zeta}}$ and $\alpha_2 = \frac{1}{\zeta - 1}(1 - \delta - \overline{\Delta N})$. $\overline{\Delta N}$ pertains to the steady state growth rate of the economy which will be discussed further in subsubsection 2.1.3.

above equations to:

$$\begin{aligned} q_t &= \frac{1}{\Lambda'_t} && (6) \\ W_t &= (1-\alpha)(1-\xi)\frac{Y_t}{L_t} && (7) \\ 1 &= E_t\left[M_{t+1}\left\{\frac{1}{q_t}\left(\alpha(1-\xi)\frac{Y_{t+1}}{K_{t+1}} + q_{t+1}(1-\delta) - \frac{I_{t+1}}{K_{t+1}} + q_{t+1}\Lambda_{t+1}\right)\right\}\right] && (8) \\ P_{i,t} &= (K_t^\alpha(\Omega_t L_t)^{1-\alpha})^{1-\xi}\nu\xi\left[\int_0^{N_t} X_{i,t}^{\frac{1}{\nu}}\, di\right]^{\nu\xi-1}\frac{1}{\nu}X_{i,t}^{\frac{1}{\nu}-1} && (9) \end{aligned}$$

2.1.2 Intermediate goods sector

A monopolistic competitive firm i at time period t produces intermediate good $X_{i,t}$ where $i \in [0, N_t]$. According to the equilibrium condition with respect to $X_{i,t}$ (Equation 9), the demand for intermediate good i depends on price $P_{i,t}$. The monopolistically competitive i produces at unit cost by considering the demand equation for $X_{i,t}(P_{i,t})$ as given. The objective of intermediate good firm i is to maximise the below profit function.

$$\max_{P_{i,t}} \Pi_{i,t} \equiv P_{i,t} \cdot X_{i,t}(P_{i,t}) - X_{i,t}(P_{i,t})$$

Using the framework in Dixit and Stiglitz (1977), we obtain the following symmetric equilibrium conditions:

$$X_{i,t} = X_t \tag{10}$$

$$P_{i,t} = P_t = \nu \tag{11}$$

where $\nu > 1$ is the markup. Substituting Equation 10 and Equation 11 into the definition for G_t (Equation 2) and the first order condition with respect to $X_{i,t}$ (Equation 9), we get

$$G_t = N_t^{\nu} X_t \tag{12}$$

$$X_t = \left(\frac{\xi}{\nu}\left(K_t^\alpha(\Omega_t L_t)^{1-\alpha}\right)^{1-\xi} N_t^{\nu\xi-1}\right)^{\frac{1}{1-\xi}} \tag{13}$$

Therefore, the profit $\Pi_{i,t}$ and dividend D_t become

$$\Pi_t = (\nu - 1)X_t \tag{14}$$

$$D_t = Y_t - I_t - W_t L_t - \nu N_t X_t \tag{15}$$

The sum of current year profits and the discounted future profits account for the value ($V_{i,t}$) of owning the patents to produce the intermediate good i.

$$V_{i,t} = \Pi_{i,t} + \phi E_t[M_{t+1} V_{i,t+1}]$$

where ϕ indicates the intermediate goods rate of survival. The symmetric equilibrium conditions are imposed so the i subscript could be dropped and the above is rewritten as

$$V_t = \Pi_t + \phi E_t[M_{t+1} V_{t+1}] \tag{16}$$

2.1.3 R&D sector

Innovation in the economy is driven by the R&D sector who develops new intermediate goods variety i and sells the new patent to firms in the intermediate goods sector. Evolution of the number of intermediate goods patents, N_t, is given by:

$$N_{t+1} = \vartheta_t S_t + \phi N_t \tag{17}$$

where S_t refers to R&D expenditures and ϑ_t indicates the productivity of the R&D sector that is taken as given by the R&D firms. The functional form of ϑ_t is given by

$$\vartheta_t = \frac{\chi \cdot N_t}{S_t^{1-\eta} N_t^{\eta}} \tag{18}$$

where $\chi > 0$ refers to the scale parameter and $\eta \in [0, 1]$ denotes the elasticity of new intermediate goods with respect to R&D. The growth rate of patents provide the equilibrium foundation of long run risk in this model.

$$\Delta N_{t+1} = \vartheta_t \frac{S_t}{N_t} + \phi \tag{19}$$

Free entry into the R&D sector implies expected sales revenue equals costs:

$$E_t[M_{t+1}V_{t+1}](N_{t+1} - \phi N_t) = S_t$$

which could also be stated in terms of marginal cost equal expected marginal revenue:

$$\frac{1}{\vartheta_t} = E_t[M_{t+1}V_{t+1}]. \tag{20}$$

2.1.4 Forcing process

The stochastic process Ω_t provides the ground for exogenous stochastic productivity shocks to the model with dynamics:

$$\Omega_t = e^{a_t}$$
$$a_t = \rho a_{t-1} + \epsilon_t, \quad \epsilon_t \sim N(0, \sigma^2)$$

2.1.5 Condition for balanced growth

Substituting equations (12) and (13) into equation (1), yields the following expression for output:

$$Y_t = \left(\frac{\xi}{\nu}\right)^{\frac{\xi}{1-\xi}} K_t^{\alpha}(\Omega_t L_t)^{1-\alpha} N_t^{\frac{\nu\xi-\xi}{1-\xi}} \tag{21}$$

The below restriction is in place to ensure balanced growth:

$$\alpha + \frac{\nu\xi - \xi}{1-\xi} = 1$$

When this restriction is imposed, it implies the standard neoclassical production function with labour augmenting technology as follows:

$$Y_t = K_t^{\alpha}(Z_t L_t)^{1-\alpha} \tag{22}$$

where Z_t is the total factor productivity (TFP):

$$Z_t \equiv \overline{A}\Omega_t N_t \tag{23}$$

and $\overline{A} \equiv \left(\frac{\xi}{\nu}\right)^{\frac{\xi}{(1-\xi)(1-\alpha)}} > 0$ is a constant.

2.1.6 Household

The utility function of the household is assumed to follow Epstein-Zin preferences over consumption $\{C_t\}$

$$Util_t = \left\{(1-\beta)C_t^{1-\frac{1}{\psi}} + \beta\left(E_t[Util_{t+1}^{1-\gamma}]\right)^{\frac{1-\frac{1}{\psi}}{1-\gamma}}\right\}^{\frac{1}{1-\frac{1}{\psi}}} \tag{24}$$

where β is the subjective discount rate, γ is the coefficient of risk aversion and ψ is the elasticity of intertemporal substitution. As in the long run risk literature, KS assume $\psi > \frac{1}{\gamma}$ so the agent prefers the early resolution of uncertainty. The preferences imply the stochastic discount factor

$$M_{t+1} = \beta\left(\frac{C_{t+1}}{C_t}\right)^{\frac{-1}{\psi}}\left(\frac{Util_{t+1}}{E_t(Util_{t+1}^{1-\gamma})^{\frac{1}{1-\gamma}}}\right)^{\frac{1}{\psi}-\gamma} \tag{25}$$

The budget constraint of the household is

$$C_t + V_{m,t}\mathcal{Z}_{t+1} + B_{t+1} = W_tL_t + (V_{m,t} + \mathcal{D}_t)\mathcal{Z}_t + (1 + r_{f,t})B_t \tag{26}$$

where $V_{m,t}t$ is the stock price, $\mathcal{Z}_t$ is the household's stock holding which pays aggregate dividend $\mathcal{D}_t$, B_t indicates bonds, $r_{f,t}$ is the risk free rate, W_t is the wage rate and L_t is the hours worked.

Following Kung and Schmid (2015), stocks are assumed to be claims to all the production sectors, such as the final good sector, the intermediate goods sector, and the R&D sector. Aggregate dividend is defined as the net payout from the production sector,

$$\mathcal{D}_t = D_t + \int_0^{N_t} \pi_{i,t}di - S_t \tag{27}$$

On account of symmetric equilibrium conditions, equation (27) could be rewritten as:

$$\mathcal{D}_t = D_t + N_t\pi_t - S_t \tag{28}$$

2.1.7 Market clearing

Final output is used for consumption, physical capital investment, purchasing intermediate goods, and R&D expenditure:

$$Y_t = C_t + I_t + N_t X_t + S_t \tag{29}$$

In the KS model without labour market friction and disutility for labour, households supply their whole labour so the labour force is normalised to one:

$$L_t = 1 \tag{30}$$

2.1.8 Asset prices

The dynamics of risk-free bond rate, the final good sector firm's stock price and the aggregate market's stock price are studied in the model. The risk-free rate is:

$$r_{f,t} = ln(R_{f,t}), \quad R_{f,t} = \frac{1}{M_{t+1}}$$

Stock price, stock return and the risk premium of final goods sector firm are given by:

$$\begin{aligned} V_{d,t} &= D_t + M_{t+1} V_{d,t+1}, \\ R_{d,t} &= \frac{V_{d,t}}{V_{d,t-1} - D_{t-1}}, \text{and} \\ r_{d,t} - r_{f,t} &= (1+l)(ln(R_{d,t}) - rf,t), \end{aligned} \tag{31}$$

respectively. The final goods sector excess return is leveraged by imposing $l = \frac{2}{3}$ as in Boldrin et al. (2001). Similarly, for aggregate market we have

$$\begin{aligned} V_{m,t} &= \mathcal{D}_t + M_{t+1} V_{m,t+1}, \\ R_{m,t} &= \frac{V_{m,t}}{V_{m,t-1} - \mathcal{D}_{t-1}}, \\ r_{m,t} - r_{f,t} &= (1+l)(ln(R_{m,t}) - rf,t) \end{aligned} \tag{32}$$

where $V_{m,t}$ is the aggregate stock price, $R_{m,t}$ is the aggregate stock return and $r_{m,t} - r_{f,t}$ is the risk premium of the aggregate market.

2.2 KS model with endogenous labour and assumed wage rigidity

Donadelli and Grüning (2016) incorporate wage rigidity into the KS model. They modify the Epstein-Zin preferences (see Equation 24) to include leisure, $leis_t$:

$$Util_t = \left\{ (1-\beta) util_t^{1-\frac{1}{\psi}} + \beta \left(E_t[Util_{t+1}^{1-\gamma}] \right)^{\frac{1-\frac{1}{\psi}}{1-\gamma}} \right\}^{\frac{1}{1-\frac{1}{\psi}}} ; \; util_t = C_t(leis_t)^{\tau} \tag{33}$$

where τ refers to the Frisch elasticity of labour supply, leisure is one minus the hours of work, $(leis_t = 1 - L_t)$. The optimal (hours of) labour supply is endogenously determined from the behavior of household from the below equation.

$$W_t^u = \frac{\partial util_t / \partial L_t}{\partial util_t / \partial C_t} = \frac{\tau C_t}{leis_t} \tag{34}$$

where W_t^u refers to optimal or frictionless wages. Donadelli and Grüning (2016) follow Uhlig (2007) in assuming that wages are sticky and evolve as

$$W_t = (W_{t-1})^{\mu} (W_t^u)^{1-\mu} \tag{35}$$

where $\mu \in [0, 1]$ is the fraction of sticky wages.

2.3 KS model with search and matching labour frictions

Instead of assuming wage stickiness as in the previous section (Equation 35), we extend the KS model with the search and matching labour market model specifications as described by Christiano et al. (2016) in this section. We continue with the Epstein-Zin preferences specified in subsubsection 2.1.6 (see Equation 24). However, we follow the definition of Christiano et al. (2016) in specifying L_t as the number of workers employed in period t with the law of motion given by

$$L_{t+1} = (\rho_1 + x_{1,t})L_t \tag{36}$$

where ρ_1 is the probability that a given match between the firm and the worker continues from one period to the next. Hence, $\rho_1 L_t$ refers to the number of workers that stays with the firm to period $t+1$. Also, $x_{1,t}L_t$ denotes the quantity of newly hired workers employed in period $t+1$. The timing convention of the law of motion of labour in equation (36) differs from Christiano et al. (2016), where the workers are engaged in production as soon as they are hired. We assume that when workers and firms meet, bargaining and work do not occur until the next period, which is standard in the labour literature [7].

In contrast to equation (30), population now includes both the employed and the unemployed in the work work force so that

$$L_t + U_t = 1 \tag{37}$$

Hence, the number of workers searching for work in period t is the number of unemployed workers in period t, U_t or $1 - L_t$. The probability, f_t, that a period t unemployed worker is employed in period $t+1$ is given by the following equation:

$$f_t = \frac{x_{1,t}L_t}{1 - L_t} \tag{38}$$

If a firm decides in period t that it wants to meet a worker, then it must post a vacancy in period t at a cost, s_t. The firm then meets a worker in period t with probability Q_t. The firm must also pay a cost κ_t upon meeting a worker. Work begins in $t+1$ as soon as a match is formed. Let J_t denote the value of a worker to the firm.

$$J_t = \eta_{1,t} - W_t + \rho_1 E_t M_{t+1} J_{t+1} \tag{39}$$

where $\eta_{1,t} = (1-\alpha)(1-\xi)\frac{Y_t}{L_t}$ is the marginal revenue associated with an additional worker hired

[7] We use the framework of standard labour literature timing convention of alternate and Nash bargaining framework from the teaching website of Lawrence Christiano: http://faculty.wcas.northwestern.edu/~lchrist/d16/d1614/take_home_final_exam.pdf

by the firm, W_t refers to wage, J_{t+1} is the value of worker to the firm in period $t+1$ and M_{t+1} is the stochastic discount factor.

In equilibrium, the firm's cost of posting a vacancy, s_t, equals the firm's expected benefit of a vacancy (net of the firm's meeting cost):

$$s_t = Q_t \left(E_t M_{t+1} J_{t+1} - \kappa_t \right) \tag{40}$$

Letting V_t^{job} denote the value of a job to a worker that pays W_t in period t then

$$V_t^{job} = W_t + E_t M_{t+1} \left[\rho_1 V_{t+1}^{job} + (1-\rho_1) V_{t+1}^{unem} \right] \tag{41}$$

The value of being an unemployed worker, V_t^{unem} is

$$V_t^{unem} = b_t + E_t M_{t+1} \left[f_t V_{t+1}^{job} + (1-f_t) V_{t+1}^{unem} \right] \tag{42}$$

where b_t refers to the unemployment benefits.

The quantity of new hires, $x_{1,t}L_t$, is a function of the number of people searching for jobs in period t, $1-L_t$ and the number of vacancies posted in t, $vac_t L_t$, based on the following matching function:

$$x_{1,t}L_t = \sigma_m (vac_t L_t)^{1-\sigma_1} (1-L_t)^{\sigma_1}, \sigma_1 \in (0,1) \tag{43}$$

where σ_1 and σ_m refer to the share of job searchers and level parameter respectively in the matching function.

The job finding rate for workers f_t and the vacancy filling rate Q_t are assumed to be related to labour market tightness, Γ_t, as

$$\Gamma_t = \frac{vac_t L_t}{1-L_t} \tag{44}$$

$$f_t = \frac{x_{1,t}L_t}{1-L_t} = \sigma_m \Gamma_t^{1-\sigma}, \quad Q_t = \frac{x_{1,t}L_t}{vac_t L_t} = \sigma_m \Gamma_t^{-\sigma} \tag{45}$$

Since a firm faces vacancy costs and hiring costs, the dividend specification changes from benchmark KS model equation (15) to the following

$$D_t = Y_t - I_t - W_t L_t - (\frac{s_t}{Q_t} + \kappa_t) x_{1,t} L_t - \nu N_t X_t \tag{46}$$

The household budget constraint now includes the unemployment benefit and lump sum taxes. Following Christiano et al. (2013), we assume that unemployment benefit b_t is provided by the government to an unemployed worker. The lump sum tax T_t paid by the household finances the unemployment benefit. The budget constraint changes from Equation 26 to the below equation.

$$C_t + V_{m,t}\mathcal{Z}_{t+1} + B_{t+1} = W_t L_t + b_t(1 - L_t) + (V_{m,t} + \mathcal{D}_t)\mathcal{Z}_t + (1 + r_{f,t})B_t - T_t \tag{47}$$

Also, the market clearing condition from Equation 29 changes to incorporate hiring costs and vacancy costs.

$$Y_t = C_t + I_t + N_t X_t + S_t + (\frac{s_t}{Q_t} + \kappa_t) x_{1,t} L_t \tag{48}$$

Based on the above framework, we have two variants of wage bargaining: Nash wage bargaining framework and Alternate Offer wage Bargaining framework (henceforth AOB). The subsequent sections provide details of wage determination under both bargaining frameworks.

2.3.1 Wage determination: Nash Bargaining

Under Nash bargaining, the wage rate corresponds to the value of W_t which is determined by the following Nash sharing rule.

$$J_t = \frac{1 - \eta_{bargain}}{\eta_{bargain}} (V_t^{job} - V_t^{unem}) \tag{49}$$

where $\eta_{bargain}$ is the share of total surplus received by the worker.

2.3.2 Wage determination: Alternate Offer Bargaining

This section provides the details of alternate offer bargaining arrangements between firms and workers following Christiano et al. (2016). As mentioned above, the timing specification makes the definition of offers and counter offers in our model different from Christiano et al. (2016) to be consistent with the standard labour literature.

As soon as the meeting occurs between a firm and a worker, a wage offer is made by the firm. The worker can accept the offer or reject it. If he accepts it, he can start working right away. If he rejects the offer, he can a) terminate bargaining or b) he can commit to come back next period to make a counteroffer. If he terminates bargaining, the worker only has the outside option. If he commits to comeback to make a counter offer, negotiations could break down with probability δ_1 in which case the firm and worker are limited to their outside options. The outside option for the worker is unemployment and the workers' value of being unemployed is denoted by V_t^{unem}. The firms' value of the outside option is zero. With probability $1 - \delta_1$, the worker returns the next period and makes a counter offer to the firm. The utility the worker receives by choosing to make a counter offer is called the disagreement payoff.

The firm's wage offer in period t is given by W_t^f. This could either be the firm's opening offer in period t or the counter offer to a worker's asking wage rejected by the firm in the previous period. In the same way, the worker's wage offer to the firm is denoted by W_t^w in case the worker had rejected the firm's wage offer in previous period.

To detail the bargaining problem, the firm would obviously prefer to propose the lowest possible wage. As it is pointless to offer a low wage which would trigger the worker to reject the offer, the firm proposes a wage that just makes the worker indifferent between accepting it and rejecting it in favor of making a counteroffer. The wage offered by the firm satisfies

$$V_t^{job,f} = max\left\{V_t^{unem}, \delta_1 V_t^{unem} + (1-\delta_1)\left[b_t + E_t M_{t+1} V_{t+1}^{job,w}\right]\right\} \tag{50}$$

where

$$V_t^{job,f} = W_t^f + E_t M_{t+1}[\rho_1 V_{t+1}^{job} + (1-\rho_1)V_{t+1}^{unem}]$$

$$V_t^{job,w} = W_t^w + E_t M_{t+1}[\rho_1 V_{t+1}^{job} + (1-\rho_1)V_{t+1}^{unem}]$$

$V_t^{job,f}$ is the worker's value of being employed at wage W_t^f in period t. In a similar manner, $V_t^{job,w}$ is the worker's value of being employed at wage W_t^w. He can be employed or unemployed in period $t+1$ with probability ρ_1 and $1 - \rho_1$, respectively.

Equation 50 shows a maximum among two options; the worker's outside option and worker's disagreement payoff. In practice, it is assumed that the latter is greater than the former. Implicit in Equation 50 is the assumption that when the worker is indifferent between accepting and rejecting an offer, he accepts it.

On the part of worker, the asking wage, W_t^w, is offered to be as high as possible without triggering a rejection by the firm. That is,

$$J_t^w = max\left\{0, \delta_1 \times 0 + (1-\delta_1)[-\gamma_{1,t} + E_t M_{t+1} J_{t+1}^f]\right\} \tag{51}$$

where

$$J_t^f = \eta_{1,t} - W_t^f + \rho_1 E_t M_{t+1} J_{t+1}$$

$$J_t^w = \eta_{1,t} - W_t^w + \rho_1 E_t M_{t+1} J_{t+1}$$

J_t^f is the firm's value of hiring the worker at wage W_t^f in period t. In a similar manner, J_t^w is the firm's value of hiring the worker at wage W_t^w. With probability ρ_1, the worker will continue being employed with the firm in period $t+1$.

In Equation 51, δ_1 is the probability that negotiations breakdown and the firm is thrown to its outside option (which is simply zero). With probability $1-\delta_1$, the firm gets to make a counteroffer at the start of the next period. The cost of making a counter offer is $-\gamma_{1,t}$ and the benefit from making a counteroffer is $E_t M_{t+1} J_{t+1}^f$. $E_t M_{t+1} J_{t+1}^f$ is the value of employing the worker at the wage W_{t+1}^f in the next period when the firm makes the counter offer. Equation 51 also shows a maximum of firm's outside option and its disagreement payoff. It is assumed that the firm's disagreement payoff is higher than its outside option.

With the assumptions of no mistakes in bargaining and of perfect information, the firm's opening offer is accepted

$$W_t = W_t^f, J_t = J_t^f, V_t^{job} = V_t^{job,f} \tag{52}$$

$V_t^{job,w}$ and J_t^w can be written as

$$V_t^{job,w} = V_t^{job} + W_t^w - W_t = V_t^{job} + dW_t \tag{53}$$

$$J_t^w = J_t - (W_t^w - W_t) = J_t - dW_t \tag{54}$$

respectively, where

$$dW_t = W_t^w - W_t$$

Using equations (50), (52) and (53), we can rewrite the indifference condition that restricts firm's offer as

$$V_t^{job} = \delta_1 V_t^{unem} + (1-\delta_1)\left[b_t + E_t M_{t+1}(V_{t+1}^{job} + dW_{t+1})\right] \tag{55}$$

Substituting equations (52) and (54) in equation (51), we obtain the below functional form for dW_t

$$dW_t = J_t - (1-\delta_1)[-\gamma_{1,t} + E_t M_{t+1} J_{t+1}] \tag{56}$$

Using equation (56) in (55), we get a dynamic version of the alternate offer sharing rule in the following equation

$$\begin{aligned} V_t^{job} &= \delta_1 V_t^{unem} \\ &\quad + (1-\delta_1)\left[b_t + E_t M_{t+1}(V_{t+1}^{job} + J_{t+1} + (1-\delta_1)\gamma_{1,t+1} - (1-\delta_1)E_t M_{t+2} J_{t+2})\right] \end{aligned} \tag{57}$$

2.3.3 Balanced growth

The source of growth in the benchmark KS model comes from the growth of intermediate goods $\Delta N_t = \frac{N_t}{N_{t+1}}$. To ensure balanced growth in the non-stochastic steady state, all elements in $[s_t, \kappa_t, \gamma_{1,t}, b_t]$ are considered to grow at the rate ΔN_t in the steady state. Hence, we have the following specification:

$$[s_t, \kappa_t, \gamma_{1,t}, b_t]' = [s, \kappa, \gamma_1, b]' \Delta N_t \quad (58)$$

3 Calibration

Parameter values used to estimate the models are presented in Panel A, Panel B and Panel C of Table 1. Panel A shows the benchmark KS model parameters calibrated following Kung and Schmid (2015). These parameters are common across all labour market specifications except for the R&D productivity parameter, χ, which is slightly adjusted to obtain identical consumption growth rates across models. Panel B shows the parameters pertaining to the wage rigidity framework following Uhlig (2007). The labour elasticity parameter, τ, is derived from the condition that household works 0.7 of its time endowment in the deterministic steady state. The wage rigidity parameter, μ, is taken from Uhlig (2007).

Panel C of Table 1 reports the parameter values of both Nash bargaining and AOB framework used in Christiano et al. (2016). The probability that negotiations break down after an offer is rejected, δ_1, is set to 0.19% , the match survival rate, ρ_1, is set to be 0.9 and the share of job searchers in the labour matching function, σ_1, is set as 0.5. These values correspond to the calibration in Christiano et al. (2016). We set the bargaining weight of worker, $\eta_{bargain}$, to equal 0.2 following Hagedorn and Manovskii (2008). The derivations of remaining model parameters such as hiring costs κ and cost of making a counter offer γ_1 are implied by the steady state properties given by Christiano et al. (2016). The first property is a value of 1 percent for the steady state ratio of hiring costs to gross output. The second property states 0.59 as counteroffer costs as a share of daily revenue. The number of business days in a quarter is assumed to be 60. These steady state properties are given in Panel C.

Based on Christiano et al. (2016), we also give empirically plausible values of 0.055 and 0.7 to unemployment rate (U_t) and vacancy filling rate (Q_t), respectively at steady state. Since we have given exogenous values to unemployment and vacancy filling rate at the steady state, the calibration of vacancy costs (s) and level parameter in matching function (σ_m) becomes endogenous.

Using the parameters and implied steady state values, we solve the model using third order perturbations around the stochastic steady state in Dynare++ 4.5.3. Moments are obtained from 200 simulations of 58 years at quarterly frequency, time-aggregated to annual frequency.

4 Results

4.1 Labour Market Dynamics

Figure 1 shows that impulse responses of labour and of wages to a productivity shock vary across models. In the benchmark KS model, labour is normalised to one since it is always fully utilised by households. Hence, labour does not respond to a shock. In the model with endogenous labour and assumed wage rigidity, labour responds the most to a productivity shock. This is due to households' willingness to supply more labour with the increase in optimal wages and the eventual increase in their actual wages. Hence, households could fully exploit the increase in productivity. In the search and matching models of Nash bargaining and AOB labour market models, the responses of labour to the productivity shock are muted in the AOB model and even more so in the Nash bargaining model. As expected, wage responds the most to a productivity shock in the frictionless benchmark KS model, followed by the responses of wage in the assumed-wage-rigidity model and then in the Nash bargaining model. The wage responds to a productivity shock the least in the AOB model. The different responses of labour and wage in the Nash bargaining and AOB models are explained below using Figure 2.

Figure 2 shows only responses of unemployment, job vacancies and job finding rates to a productivity shock for Nash bargaining and AOB models–whereby the Nash bargaining model shows more muted responses compared with the AOB model. There are no impulse responses associated with vacancy, unemployment and job finding rates in the benchmark KS model since labour is normalised as one. The same applies to the wage rigidity model as the sum of labour–defined as hours of work–and leisure is equal to one.

The weak effects of a productivity shock on unemployment, vacancies and job finding rate in the Nash bargaining model are closely related to the Shimer (2005) critique of the conventional search and matching models as in Diamond (1982), Mortensen (1982) and Pissarides (1985) (DMP). Nash bargained wage is a weighted average of the worker's job productivity and the value of being unemployed. Value of the outside option (being unemployed) is dependant on the wages offered in other jobs. According to Shimer (2005), a positive productivity shock increases all employers reservation wages. If both the job productivity and the value of being unemployed (derived from all other employers reservation wages) increase by the same amount, there would not be any change in the employer's recruiting effort and unemployment would be stable in a nash bargaining framework. However, the alternate offer bargained wage no longer depends on the procyclical outside options (value of being unemployed) but instead on the a-cyclical disagreement payoffs. This affects the recruiting effort of employer and unemployment fluctuates drastically in the AOB framework. Hence, Figure 2 shows that the AOB model generates a sharp decline in the unemployment rate together with a large increase in job vacancies and the job finding rate. Therefore, the estimated AOB model is not subject to Shimer (2005) critique of search and matching models with low replacement rates.

Table 2 reports the aggregate labour market moments from the data and from stochastic simulation of the Nash bargaining and AOB models. We can see from Table 2 that AOB in the search and matching framework produces volatility statistics closer to the data than Nash bargaining. The AOB model also accounts for the unconditional correlations between these variables. The results of Table 2 make it evident that AOB does better in accounting for the cyclical properties of key labour market variables than the other models.[8]

4.2 Aggregate Quantity Dynamics

Figure 3 shows the impulse responses of consumption, investment and output to a positive productivity shock in the benchmark KS, the wage rigidity, Nash bargaining and the AOB models. The figure shows that consumption volatility is highest in the benchmark KS model followed by the wage-rigidity model, then the Nash bargaining model and the least in the AOB model. Households' consumption rises the most in the benchmark KS model as it uses its full endowment of labour and its wages rise the most at close to 0.14% (as shown in Figure 1) in response to a positive productivity shock. The response of consumption is second highest in the wage-rigidity-with- endogenous-labour-supply model in response to a productivity shock. This is due to households providing more labour (hours) as wages rise around 0.13%. More labour

[8] Christiano et al. (2013) report higher volatilities for the Nash bargaining and AOB framework but unlike the benchmark KS model, their model has Calvo-type price rigidities.

(hours)–but still less than full endowment of labour–translate to higher earnings so households increase consumption but by less than in the benchmark KS model.

Figure 3 also shows the lower responses of consumption to a positive productivity shock in the search and matching models compared to the benchmark KS and wage rigidity models. In the search and matching models, the presence of unemployment benefits acts as an automatic stabiliser which reduces the sensitivity of consumption to the productivity shock. A positive productivity shock results in a rise in unemployment benefits. By the wage sharing rules, the effect of rise in unemployment benefits on wages is less in AOB when compared to Nash bargaining framework as alternate offer sharing rule consists of a cost of delay in making a counteroffer. On account of relatively low increase in earnings following a positive productivity shock, agents under alternate offer sharing rule consume less when compared to agents under Nash sharing rule.[9]

The impulse responses of investment and output to a positive productivity shock are also shown in Figure 3. The figure shows the responses of both investment and output are the most in the benchmark KS model followed by the AOB model, the Nash bargaining model, and the least in the wage rigidity model.

4.3 Asset Pricing Implications

One of the main shortcoming of the standard production based asset pricing models is the inability to capture the cyclical behavior of dividend (Kung and Schmid, 2015; Favilukis and Lin, 2016). In standard models, dividend equals output minus investment minus labour cost. Since wages are perfectly correlated to output and investment is procyclical, dividend is countercyclical in standard models. In contrast, Figure 4 shows dividend to be acyclical in the benchmark KS model, slightly procyclical in the wage rigidity model, moderately procyclical in the Nash bargaining model and highly procyclical in the AOB model. The acyclicality in the KS model can be attributed to the different definition of dividend in benchmark KS model compared to the other standard asset pricing models. Dividend in the KS model includes expenses on intermediate goods costs.

The same definition of dividend is used when wage rigidity is assumed in the KS model.

[9]Households also earn from dividends but these are small compared to labour income. The responses of dividends to a positive productivity shock in various models are discussed the next section.

However, dividend becomes slightly procyclical on account of wages being rigid and smoother than the marginal product of labour and output. Under search and matching models, the dividend definition now incorporates both vacancy cost and the cost of meeting a worker by the firm. Both these costs decline during periods of expansion, thereby enabling dividends to be more procyclical. The response of AOB determined wage to a positive productivity shock is more muted than the response witnessed by Nash determined wage. This causes the AOB model dividend to be more procyclical that the Nash model dividend.

Table 3 confirms this procylical behaviour of dividends as the correlation between dividend and output is highest under the AOB model. The moments associated with volatility of dividends also slightly improves under the AOB model. However, the volatility moment of P/D ratio overshoots the data counterpart under the AOB model.

Table 4 shows marginal improvement in the the asset pricing moments after labour market model is incorporated in the benchmark KS model. The equity premium moment under AOB model is very close to its data counterpart. This can be explained using the long run risk component of the benchmark model. Kung and Schmid (2015) describe about how agent's fear about periods of economic downturn and the associated low valuation of assets cause the agent to demand a higher equity premium. There are two points to the search and matching model associated with long run risk that makes the equity premium more closer to the data. Firstly, the presence of unemployment in the model increases long run risk. Periods of economic downturn are associated with relatively higher levels of unemployment. Hence, the agent may fear of being unemployed and being limited to unemployment benefits instead of wages. Since wages are not perfectly correlated with output, wages are relatively higher than unemployment benefits during periods of economic downturn. Such a fear of cashflow risk may force the agent to command an even higher equity premium under the search and matching market model

The second point is with respect to the cyclical behaviour of dividends and the performance of AOB model to explain equity premium. In the benchmark KS model, the agent's cashflow associated with dividend is acyclical. But in the AOB model, highly pro cyclical dividend causes agent's dividend to decline even further when compared to benchmark KS model during periods of economic downturn. With long run risk and the agent's preference for consumption smoothing in the model, higher equity premium under AOB can be associated with the agent's perceived fear of being limited to unemployment benefits and smaller dividend during economic downturn. The volatility of risk premium falls short of their empirical counterparts as given in Table 4. As mentioned by Kung and Schmid (2015), this shortcoming could be due to the non incorporation of short run risks, which may not be entirely productivity driven.

With regard to the risk free rate moment, we find that the mean of the risk free rate estimated by the models with labour market dynamics falls short of the benchmark KS model. Intuitively, an explanation for such a slight decrease in risk free rate lies with the agents preference for saving to prepare for persistent low growth episodes. With dividends being more procyclical when compared to the benchmark KS model, agents tend to save more to smooth the consumption during periods of low growth. Table 4 also shows that the volatility of the risk free asset improves in the presence of wage inertia with AOB model more closer to the data.

In the context of declining labour share and rising firm concentration, we also conduct sensitivity analysis to find the impact of labour share (1-α) and intermediate good firm monopoly markup (ν) on the performance of equity premium in the AOB model. Table 5 shows the equity premium for 1-α equals 0.7, 0.65 and 0.6 in the AOB model with all other calibration parameters remaining the same as in Table 1. We find that the equity premium rises when labour share declines in the production function. On the other hand, Table 6 shows the equity premium for ν equals 1.55, 1.65 and 1.75 in the AOB model with all other calibration parameters remaining the same as in Table 1. Table 6 shows that increase in firm markup (ν) results in a decline of the equity premium.

5 Conclusion

The results from our study depict the importance of incorporating labor market elements in production based asset pricing model. We extend the Kung and Schmid (2015) with a search and matching labor market with nash bargaining framework and alternate offer bargaining framework following Christiano et al. (2016). We also replicate Donadelli and Grüning (2016)'s extension of the Kung and Schmid (2015) to include wage rigidities as in Uhlig (2007). Among the aforementioned labor market models, rent sharing rule based on alternate bargaining framework in a search and matching model framework captures the key asset pricing moments and aggregate macroeconomic quantities found empirically.

Our contribution to the labor asset pricing literature stems from understanding the labor market implications of long run risk which endogenously arise in the Kung and Schmid (2015) model. The long run risk channel which makes the agents fear about persistent economic downturn in the future is aggravated further with the unemployment that accompanies such downturns. As alternate offer bargaining framework is better able to replicate the responses of unemployment to productivity shock, this channel makes the cash flow risk (uncertainty over wage flow) of agents higher resulting in them commanding higher risk premia over assets held.

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Table 1: Parameters and steady state values

Parameter	Description	Value		Source
Panel A: Common parameters				
β	Subjective discount factor	0.9945		
ψ	Elasticity of intertemporal substitution	1.8		
γ	Risk aversion	10		
ξ	Patent share	0.5		
ν	Inverse markup	1.65		
α	Capital share	0.35		KS (2015)
ρ	Productivity shock persistence	0.9925		
χ	R&D productivity parameter	0.343		
ϕ	Patent obsolescence rate	0.0375		
η	Elasticity of new patents with respect to R&D	0.83		
δ	Depreciation rate of capital stock	0.02		
ζ	Investment adjustment cost parameter	0.8		
Panel B: Wage rigidity				
χ	R&D productivity parameter	0.462		KS (2015) and authors' calculations
τ	labour elasticity	0.38		Uhlig (2007)
μ	Sticky wage parameter	0.2		Uhlig (2007)
Panel C: Search and matching				
Parameters		Nash rule	AOB	
$100\delta_1$	Prob. of bargaining session break-up	-	0.19	CET (2016)
ρ_1	Job survival probability	0.9	0.9	CET (2016)
σ_1	Share of job searchers	0.5	0.5	CET (2016)
$\eta_{bargain}$	Total surplus share received by workers	0.2	-	Hagedorn and Manovskii (2008)
κ	Hiring cost to meet a worker	0.0431	0.0431	CET (2016) and and authors' calculations
γ_1	Counteroffer costs	-	0.0014	CET (2016) and authors' calculations
b	Unemployment benefits	0.0043	0.0031	CET (2016) and authors' calculations
s	Vacancy cost	0.80	0.83	CET (2016) and authors' calculations
σ_m	Level parameter in matching function	1.097	1.097	CET (2016) and authors' calculations

Notes: The table reports the quarterly calibrations of the four models considered in this study. Panel A: KS benchmark model. Panel B: Wage rigidities following Uhlig (2007). Panel C: Search and matching model following Christiano et al. (2016). CET (2016) refers to Christiano et al. (2016)

Table 2: Labour market moments

Moments	Data	Benchmark KS	Wage rigidity	Nash Bargaining	AOB
$\sigma(u)$	13.00%	-	-	6.77%	11.34%
$\sigma(vac)$	14.00%	-	-	8.13%	12.8%
$\sigma(\frac{vac}{u})$	26.00%	-	-	14.81%	24.04%
$corr(u,v)$	-0.860	-	-	-0.975	-0.984
$corr(u,v/u)$	-0.960	-	-	-0.999	-0.999
$corr(v,v/u)$	0.98	-	-	0.977	0.986

Note: This table reports the aggregate labour market moments obtained from a stochastic simulations of the relevant models. The model is solved using third-order perturbations around the stochastic steady state in Dynare++ 4.4.3. The moments in the data column are from Christiano et al. (2013) for the period 1951–2008. The benchmark KS model and the wage rigidity model show no moments associated with vacancy and unemployment since the labour force is fixed at unity in KS benchmark model and the sum of labour (defined as hours of work) and leisure is equal to one in the wage rigidity model. Model (1): KS benchmark model. Model (2): Wage rigidities following Uhlig (2007). Model (3): Nash bargaining framework in search and matching labour model following Christiano et al. (2016) Model(4):Alternate offer bargaining framework in search and matching labour model following Christiano et al. (2016). All data are in log levels.

Table 3: Dividend and P/D ratio moments

Moments	Data	Benchmark KS	Wage rigidity	Nash Bargaining	Alternate Offer Bargaining
$\sigma[\Delta d]$	2.60%	2.34%	2.93%	1.82%	2.68%
$\sigma[p-d]$	41.54%	15.06%	11.92%	10.73%	74.08%
$\sigma[d]/\sigma[y]$	1.40	0.20	0.35	1.18	1.30
$corr(d,y)$	0.968	0.093	0.842	0.986	0.988
$\sigma[\Delta d]/\sigma[\Delta y]$	2.62	1.02	1.18	0.77	1.13
$corr(\Delta d, \Delta y)$	0.42	0.39	0.60	0.40	0.50

Note: This table reports the dividend and output ratio moments obtained from a stochastic simulation of the four models considered in this study. The model is solved using third-order perturbations around the stochastic steady state in Dynare++ 4.5.3. The moments in the data column except for P/D ratio are calculated from the data obtained from Federal Reserve Bank of St. Louis for the period 1953–2008. The volatility moment of P/D ratio in the data column is taken from Kung and Schmid (2015). Model (1): KS benchmark model. Model (2): Wage rigidities following Uhlig (2007). Model (3): Nash bargaining framework in search and matching labour model following Christiano et al. (2016) Model(4):Alternate offer bargaining framework in search and matching labour model following Christiano et al. (2016). Variables considered are log dividend (d) and log output (y)

Table 4: Asset pricing moments

Moments	Data	Benchmark KS	Wage rigidity	Nash Bargaining	Alternate Offer Bargaining
$E(r_m - r_f)$	4.89%	3.07%	3.46%	3.93%	4.41%
$\sigma(r_m - r_f)$	17.92%	3.88%	4.05%	3.67%	3.52%
$E(r_f)$	2.90%	1.09%	1.02%	0.78%	1.05%
$\sigma(r_f)$	3.00%	0.35%	0.38%	0.39%	0.41%

Note: This table reports the asset pricing moments obtained from a stochastic simulation of the four models considered in this study. The model is solved using third-order perturbations around the stochastic steady state in Dynare++ 4.5.3. The moments in the data column are from Papanikolaou (2011) for the period 1951–2008. Model (1): benchmark KS model. Model (2): Wage rigidities following Uhlig (2007). Model (3): Nash bargaining framework in search and matching labour model following Christiano et al. (2016) Model(4):Alternate offer bargaining framework in search and matching labour model following Christiano et al. (2016).

Table 5: Effect of varying α on the equity premium in AOB model

	$1-\alpha = 0.7$	$1-\alpha = 0.65$	$1-\alpha = 0.6$
$E(r_m - r_f)$	3.81%	4.41%	7.29%

Note: This table reports the asset pricing moments obtained from a stochastic simulation of the four models considered in this study. The model is solved using third-order perturbations around the stochastic steady state in Dynare++ 4.5.3. The moments are computed using alternate offer bargaining framework in search and matching labour model following Christiano et al. (2016).

Table 6: Effect of varying ν on the equity premium in AOB model

	$\nu = 1.55$	$\nu = 1.65$	$\nu = 1.75$
$E(r_m - r_f)$	4.58%	4.41%	4.31%

Note: This table reports the asset pricing moments obtained from a stochastic simulation of the four models considered in this study. The model is solved using third-order perturbations around the stochastic steady state in Dynare++ 4.5.3. The moments are computed using alternate offer bargaining framework in search and matching labour model following Christiano et al. (2016).

Figure 1: Impulse Responses to a positive productivity shock: Nash vs. AOB in Labor (L_t) and Wages (W_t); x-axis in quarters; y-axis in percentage

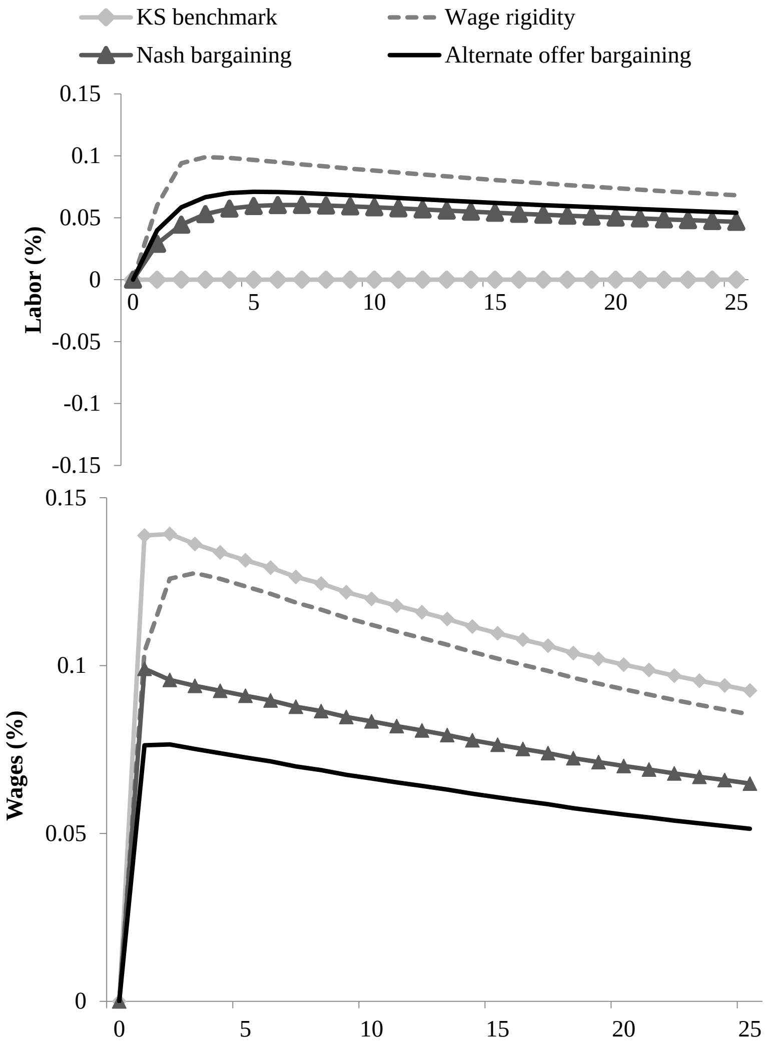

Figure 2: Impulse Responses to a positive productivity shock: Nash vs. AOB in Unemployment (U_t), Vacancies (Vac_tL_t) and job finding rate (f_t); x-axis in quarters; y-axis in percentage

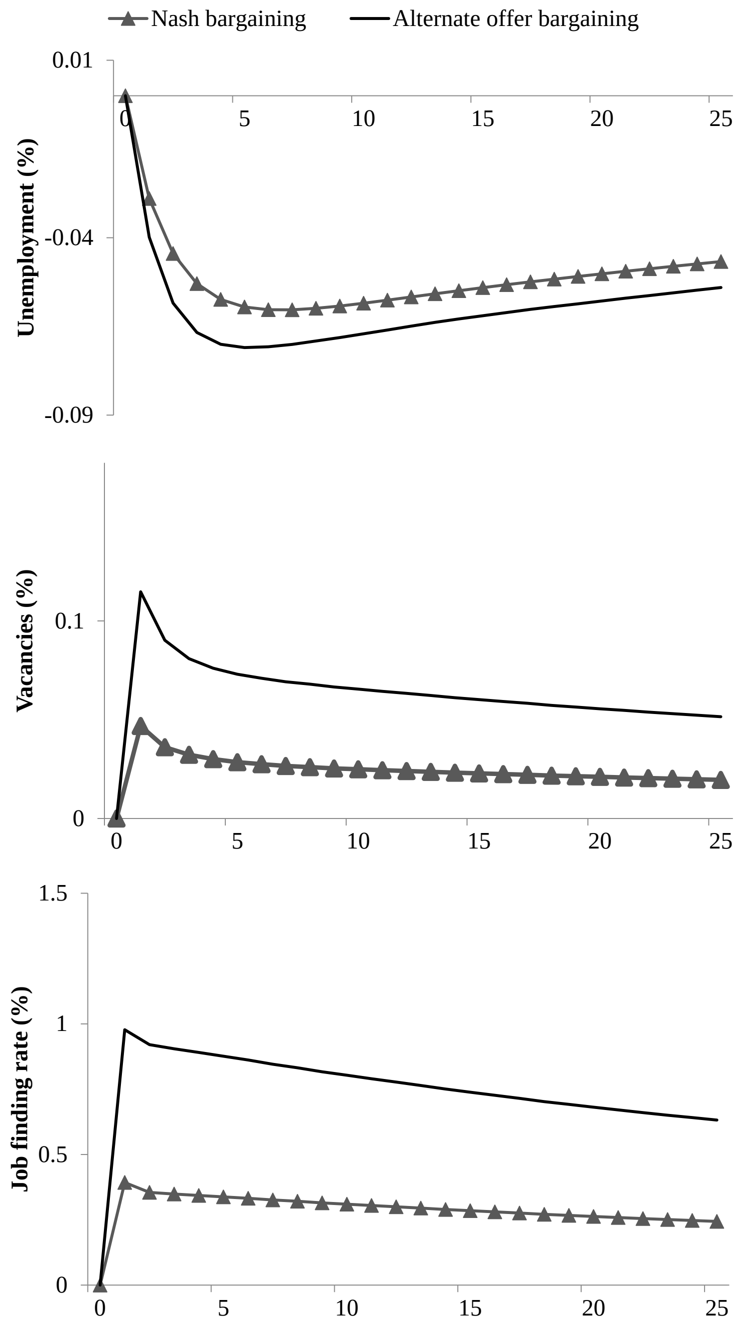

Figure 3: Impulse Responses to a positive productivity shock: Benchmark vs. Wage rigidity vs. Nash vs. AOB in Consumption (C_t), Investment (I_t) and Output (Y_t) x-axis in quarters; y-axis in percentage

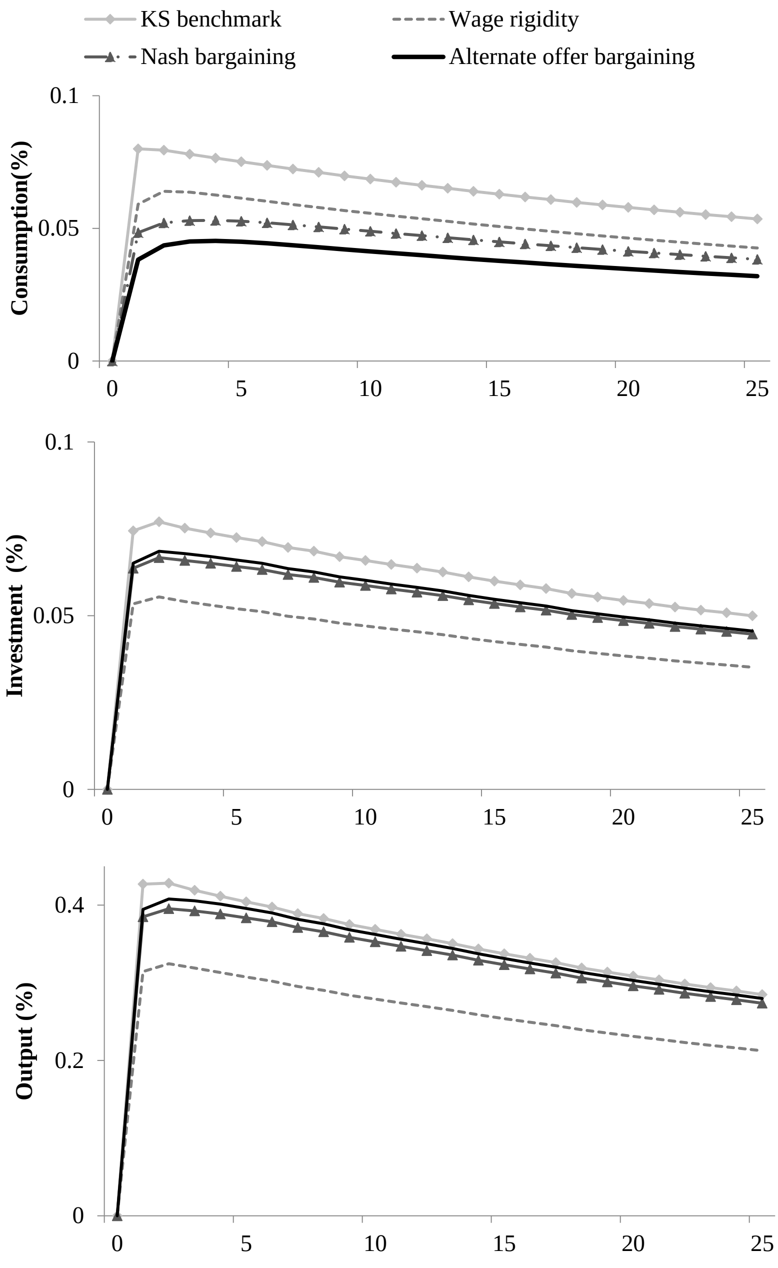

Figure 4: Impulse Responses to a positive productivity shock: Benchmark vs. Wage rigidity vs. Nash vs. AOB in Dividend (D_t); x-axis in quarters; y-axis in percentage