Costly Labor Reallocation, Non-Separable Preferences, and Expectation Driven Business Cycles *

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PRELIMINARY

Abstract

A key feature of the business cycle data is that output, employment and investment move up and down together in different sectors of the economy. However, standard business cycle models fail to generate this business cycle sectoral co-movement. In this paper we propose a two-sector business cycle model that generates the sectoral co-movement in response to both contemporaneous shocks and news shocks about fundamentals. The key elements to the model's success are frictions in intersectoral labor mobility and non-separable preferences in consumption and leisure, along with adjustment costs to investment and variable capital utilization. We estimate and compare two alternative mechanism of generating the sectoral co-movement by using a Bayesian approach. It appears that the data decisively support our proposed mechanism of generating the sectoral co-movement.

Keywords: Sectoral Co-movement; News Shocks; Expectation Driven Business Cycles.
JEL Classification: E32; E13

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1 Introduction

Recently, there has been a revival of the idea that economic fluctuations are not driven only by contemporaneous shocks but often influenced by changes in expectations about future fundamentals (hereafter, news shocks). However, as Beaudry and Portier (2004) point out, changes in expectations cannot generate the observed strong business cycle co-movement in output, hours worked, and investment across sectors of the economy in standard multi-sector neoclassical business cycle models.

Several papers propose a multi-sector model that generates the business cycle sectoral co-movement in simple neoclassical settings. For example, Jaimovich and Rebelo (2009) demonstrate that along with variable capital utilization and investment adjustment costs, it is essential to use preferences exhibiting very small labor supply wealth effects in order to generate the sectoral co-movement. Beaudry and Portier (2004) show that a strong complementarity between nondurable and durable goods in the utility function can overcome the sectoral co-movement problem. Beaudry and Portier (2007) identify the multi-sector setting, where intermediate goods firms supplying different inputs to different sectors of the economy exhibit cost complementarity (i.e., economies of scope), as being necessary for obtaining the sectoral co-movement.

However, the features proposed in the literature to overcome the sectoral co-movement problem seem to be at odds with the data or lack of empirical evidence. Kimball and Shapiro (2008) provide empirical evidence suggesting that there are sizable wealth effects on labor supply. While Beaudry and Portier (2004) argue that it is reasonable to assume the complementarity between nondurable goods and infrastructure, the existing empirical studies seem to suggest that, in general, nondurable and durable goods consumption are not complements. Ogaki and Reinhart (1998) estimate the intratemporal elasticity of substitution between nondurable consumption and durable goods consumption and find that this elasticity is greater than one, implying that nondurable goods and consumer durable goods are substitutes. Piazzesi, Schneider, and Tuzel (2007) also find that nondurables and housing are substitutes. Finally, there is not much convincing empirical support on the magnitude of the economies of scope. Hence, it seems difficult to evaluate whether the degree of economies of scope necessary to support the expectation driven business cycles in Beaudry and Portier (2007) is empirically plausible or not.

This paper presents a simple two-sector neoclassical business cycle model that generates the co-movement without assuming very small wealth effects on labor supply and multi-product producers experiencing cost complementarity, and without taking a direct stand on whether nondurable and durable goods are complements or substitutes. The key characteristics which we identify as producing the sectoral co-movement are the non-separable preferences in consumption and labor supply and limited labor mobility across sectors, in combination with investment adjustment costs and variable capital utilization. Of course, previous papers have considered limited inter-sectoral labor mobility and non-separable preferences in neoclassical models with contemporaneous shocks, but to our knowledge none of them have explored the implications that these features have in the context of news shocks. Investment adjustment costs and variable capital utilization are common ingredients of models that incorporate news shocks.

Compared to Jaimovich and Rebelo (2009), and Beaudry and Portier (2004, 2007), the strength of this paper is that it embeds more empirically realistic features to resolve questions of co-movement. Basu and Kimball (2002), Guerron-Quintana (2008), and Kim and Katayama (2010) present compelling evidence that the data reject additively separable preferences against non-separable preferences. Regarding labor mobility, Phelan and Trejos (2000) provide evidence that even very small search-and-matching costs may substantially slow down intersectoral labor movements after a sectoral shift in demand. Davis and Haltiwanger (2001) find limited labor mobility across sectors in response to monetary and oil shocks. Horvath (2000) reports a relatively low estimate for the elasticity of substitution of labor across sectors. In order to ensure that our proposed mechanism of generating the sectoral co-movement is supported by the data, especially against the two-sector version of the model considered in Jaimovich and Rebelo (2009), we estimate and compare two alternatives by using a Bayesian approach.

While we focus on the *sectoral* co-movement in output, investment and hours worked, another strand of literature on the news shocks has examined a different form of co-movement, *aggregate* co-movement, using one-sector business cycle models. Jaimovich and Rebelo (2009) refer to aggregate co-movement as the co-movement among the major aggregate macroeconomic variable such as output, consumption, investment, and hours worked. It is also difficult for a standard one-sector neoclassical model to generate the aggregate co-movement in response to news shocks. Several recent papers propose a one-sector model that produces the aggregate co-movement. Exemplary papers are Christiano, Ilut, Motto, and Rostagno (2008), Den Haan and Kaltenbrunner (2009), Eusepi and Preston (2009) and Jaimovich and Rebelo (2009), among others.

The remainder of the paper is organized as follows. Section 2 presents our two-sector business cycle model. Section 3 presents an analytical characterization on the condition for the sectoral co-movement in hours worked. In Section 4, we calibrate and simulate the model to show that the business cycle co-movement can be obtained without assuming very small labor supply wealth effects. We also discuss the role that each element in our model plays in generating the co-movement and study the sensitivity of our results. In order to examine empirical plausibility of our model, we estimate the model with a Bayesian approach in Section 5. Furthermore, we compare our model with the two-sector version of Jaimovich and Rebelo (2009). Then, Section 6 concludes.

2 The Model

Our model adopts the basic structure of the two-sector model of Jaimovich and Rebelo (2009) but differs from their model in two respects. Jaimovich and Rebelo (2009) use the preferences parameterizing the strength of wealth effects on the labor supply. These preferences nest the class of the King-Plosser-Rebelo utility function and the utility function proposed by Greenwood, Hercowitz, and Huffman (1988), which eliminates the wealth effects on labor supply, as special cases. In contrast, we restrict our focus on the King-Plosser-Rebelo utility function to show that our model is capable of generating the business cycle co-movement without assuming very low wealth effects on the labor supply. We introduce costs of adjusting labor across sectors, whereas Jaimovich and Rebelo (2009) assume that labor can flow freely across sectors.

2.1 Households

The economy is populated by a constant number of identical and infinitely-lived households. The representative household receives utility from consumption and incurs disutility from providing labor hours to the consumption and investment goods sectors. Let C_t and N_t respectively denote period t consumption and an aggregate labor index. Households maximize the expected lifetime utility as given by

$$U_0 = E_0\left[\sum_{t=0}^{\infty}\beta^t U(C_t, N_t)\right], \tag{1}$$

where $\beta \in (0,1)$ is the subjective discount factor.

The specific form of the King-Plosser-Rebelo utility function adopted in this paper is

$$U(C_t, N_t) = \frac{C_t^{1-\frac{1}{\sigma}}\left(1+\left(\frac{1}{\sigma}-1\right)v(N_t)\right)^{\frac{1}{\sigma}} - 1}{1-\frac{1}{\sigma}}, \tag{2}$$

where $v(N_t) = \varphi\frac{\eta}{1+\eta}N_t^{\frac{\eta+1}{\eta}}$. This class of the King-Plosser-Rebelo utility function is used in Basu and Kimball (2002) and Shimer (2009). $v(N_t)$ measures the disutility incurred from hours worked with $v^{'} > 0$, $v'' > 0$. η is the Frisch elasticity of aggregate labor supply, measuring the intertemporal elasticity of aggregate labor supply.[1] For lower values of η, agents are unwilling to substitute aggregate labor supply over time.

Our formulation of monetary utility function nests the non-separable and separable preferences in consumption and leisure. In (2), the degree of non-separability is controlled by the parameter for intertemporal elasticity of substitution for consumption, σ. The non-separable cases arise when $\sigma < 1$, which implies that consumption and leisure are substitutes as predicted by theory of time allocation (Becker, 1965). In other words, the marginal utility of consumption is decreasing in leisure. The lower this parameter is, the larger the substitutability between consumption and leisure displayed by the utility function. The separable case corresponds to the limiting case $\sigma \to 1$,

$$\lim_{\sigma\to 1} U(C_t, N_t) = \log(C_t) - v(N_t).$$

This separable preference is used in most business cycle models.

We assume that the representative household is endowed with one unit of time in each period one and the aggregate leisure index L_t takes the following form:

[1]It can be easily shown that the inverse Frisch elasticity of labor supply (i.e., the marginal utility of consumption (λ) constant elasticity) is

$$\left(\frac{\partial logW}{\partial logN}\right)_{\lambda=const.} = \left[U_{NN} - (U_{CN})^2/U_{CC}\right]/U_N,$$

where λ is the marginal utility of consumption and W is the real wage. After some algebra, one can show that the inverse Frisch elasticity reduces to $1/\eta$.

$$L_t = 1 - N_t = 1 - \left[N_{c,t}^{\frac{\theta+1}{\theta}} + N_{i,t}^{\frac{\theta+1}{\theta}} \right]^{\frac{\theta}{\theta+1}}, \quad \theta \geq 0. \tag{3}$$

Here N_t is an aggregate labor hours index, and $N_{c,t}$ and $N_{i,t}$ respectively denote labor hours devoted to the consumption and investment sector. This specification is considered by Huffman and Wynne (1999) and Horvath (2000) to capture some degree of sector specificity to labor, while not deviating from the representative worker assumption. The degree to which labor can move across sectors is controlled by the elasticity of *intra*temporal substitution in labor supply, θ. As $\theta \to \infty$, labor hours become perfect substitutes for the worker, implying that the worker would devote all time to the sector paying the highest wage. Hence, at the margin, all sectors pay the same hourly wage. For $\theta < \infty$, hours worked are not perfect substitutes for the worker. The worker has a preference for diversity of labor, and hence would prefer working positive hours in each sector, even when the wages are different among sectors. In the limit as $\theta \to 0$, it is impossible to alter the composition of labor hours. In other words, there is an infinite cost of doing so and consequently the labor hours in two different sectors will be perfectly correlated. Below, we will derive the threshold level of θ needed for producing the sectoral co-movement of hours worked.

When building models with non-separable preferences to analyze business cycle fluctuations, Bilbiie (2009) emphasizes that one needs to check the conditions for the overall concavity of momentary utility function and the normality of consumption and leisure. It is straightforward to show that if $\sigma \leq 1$, the overall concavity of $U(\cdot)$ is guaranteed, i.e., $U_{CC} \leq 0$, $U_{LL} \leq 0$, and $U_{CC}U_{LL} - (U_{CL})^2 \geq 0$. To ensure that consumption and leisure are normal goods, the constant-consumption labor supply needs to be upward sloping,[2] i.e., the following restriction to $U(\cdot)$ needs to hold:

$$-\left(N\frac{U_{LL}}{U_L} - N\frac{U_{CL}}{U_C} \right) = -\omega_N + \frac{v''(N)N}{v'(N)} > 0, \tag{4}$$

[2]To be more precise, Bilbiie (2009) shows that both consumption and leisure are normal goods if

$$\frac{(U_{CL}/U_L) - (U_{CC}/U_C)}{(U_{LL}/U_L) - (U_{CL}/U_C)} < 0.$$

It is straightforward to show that the numerator is always positive in our momentary utility function. Hence, to ensure the normality of consumption and leisure, the denominator, constant-consumption labor supply, should be positive.

where $\omega_N \equiv \frac{(\frac{1}{\sigma}-1)v'(N)N}{(1+(\frac{1}{\sigma}-1)v(N))}$ and $\lim_{\sigma\to 1}\omega_N = 0$. It can be shown that ω_N can be expressed as

$$\omega_N = (1-\sigma)\left(\frac{N}{N_c}\right)^{\frac{1}{\theta}+1}\frac{W_c N_c}{P_c C} \geq 0.$$

The household faces a standard budget constraint

$$C_t + \left(\frac{P_{i,t}}{P_{c,t}}\right)(I_{c,t}+I_{i,t}) \leq \sum_{j=c,i}\left(\frac{W_{j,t}}{P_{c,t}}\right)N_{j,t} + \sum_{j=c,i}\left(\frac{R_{j,t}}{P_{c,t}}\right)u_{j,t}K_{j,t}, \tag{5}$$

where the subscripts c and i denote variables that are specific to the consumption and investment sector, respectively. $P_{j,t}$ is the nominal price of goods produced in sector $j = c, i$; $I_{j,t}$ represents newly purchased capital for sector j; $W_{j,t}$ is the nominal wage rate paid by firms in sector j. In addition, $K_{j,t}$ is a productive capital stock in sector j, and $u_{j,t}$ denotes the capital utilization rate in sector j. Hence, $u_{j,t}K_{j,t}$ represents the capital services and $R_{j,t}$ is the rental rates of capital services in sector j.

The capital stock in each sector $j = c, i$ evolves according to

$$K_{j,t+1} = I_{j,t}\left[1-\phi_K\left(\frac{I_{j,t}}{I_{j,t-1}}\right)\right] + [1-\delta(u_{j,t})]K_{j,t}, \quad j = c, i. \tag{6}$$

Here $\phi_K(\cdot)$ represents adjustment costs incurred by the household, when the level of investment changes over time. We assume that $\phi_K(1) = 0$, $\phi_K'(1) = 0$, so that there are no adjustment costs in the steady state, and that $\phi_K''(1) > 0$. The function $\delta(\cdot)$ represents the variable depreciation rate. We assume that the depreciation rate is convex in the rate of utilization: $\delta' > 0$, $\delta'' \geq 0$.

2.2 Firms

The two types of final goods produced in the economy are consumption goods, produced in the consumption sector, and capital goods, produced in the investment sector. Firms in the investment sector provide new investment goods to both sectors. Output in each sector is produced by perfectly competitive firms with the Cobb-Douglas production function

$$C_t = A_t z_{c,t}(u_{c,t}K_{c,t})^{\alpha}(N_{c,t})^{1-\alpha}, \tag{7}$$

$$I_t = I_{c,t} + I_{i,t} = A_t z_{i,t}(u_{i,t}K_{i,t})^{\alpha}(N_{i,t})^{1-\alpha}, \tag{8}$$

where A_t is the level of aggregate total factor productivity (TFP) and $z_{j,t}$ is the level of sectoral TFP in the sector $j = c, i$. Unlike Beaudry and Portier (2007), we do not incorporate a multi-product good producer that sells potentially different intermediate goods to the consumption and investment sector. Hence, our setup does not allow for the property that the marginal cost of producing an intermediate good for one sector decreases with the production of a different intermediate good for another sector, generally referred to as a cost complementarity.

The driving processes for A_t and $z_{j,t}$ are given by

$$\widehat{A_t} = \rho_a \widehat{A}_{t-1} + v^0_{a,t} + v^p_{a,t-p}, \tag{9}$$

$$\widehat{z}_{j,t} = \rho_j \widehat{z}_{j,t-1} + v^0_{j,t} + v^p_{j,t-p}, \quad j = c, i, \tag{10}$$

where a circumflex ("hat") over a variable represents proportionate deviations of that variable from its steady state. $v^p_{j,t-p}$ for $j = a, c, i$ and for $p = 0, \cdots, p$, are i.i.d disturbances. The shock $v^0_{j,t}$ represents a conventional contemporaneous TFP shock or a sectoral TFP shock to the consumption and investment sectors, and $v^p_{j,t-p}$ represents the shock that affects the aggregate TFP or the sectoral TFP p periods later. In other words, the shock $v^p_{j,t}$ does not affect the current aggregate TFP or the sectoral TFP, but provides information about its p-period ahead evolution.

3 Employment co-movement

Before numerically solving the model, it is useful to provide analytical characterization on the condition for the model economy to display the co-movement in hours worked across sectors. For that purpose, we derive the equilibrium condition for employment in the consumption sector. This is obtained from equating the labor demand in the consumption sector determined by the marginal product of labor with labor supply determined by the marginal rate of substitution between leisure and consumption:

$$-\frac{\frac{\partial U}{\partial L}\frac{\partial L}{\partial N_c}}{\frac{\partial U}{\partial C}} = \frac{1}{\sigma}\frac{C_t}{\left(1 + \left(\frac{1}{\sigma} - 1\right) v(N_t)\right)} \varphi N_t^{\frac{1}{\eta}} \left(\frac{N_{c,t}}{N_t}\right)^{\frac{1}{\theta}} = (1-\alpha)\frac{C_t}{N_{c,t}}. \tag{11}$$

In contrast with a conventional equilibrium condition with perfect labor substitutability (i.e., $\theta = \infty$), there is an additional term, $\left(\frac{N_{c,t}}{N_t}\right)^{\frac{1}{\theta}}$, which makes the sectoral co-movement of hours worked possible. To see this, let us define aggregate nominal wage as $W_t = \left[W_{c,t}^{1+\theta} + W_{i,t}^{1+\theta}\right]^{\frac{1}{\theta+1}}$.[3] Using this, it is easy to show that $\left(\frac{N_{c,t}}{N_t}\right)^{\frac{1}{\theta}}$ is equal to the relative wage in the consumption sector, $\frac{W_{c,t}}{W_t}$. Suppose now that aggregate hours worked rise because of an expansion in the investment sector and thus the marginal disutility of aggregate hours worked increases. Then, aggregate nominal wage and nominal wage in the investment sector increase relative to nominal wage in the consumption sector. In case of perfect labor substitutability, labor flows from the consumption sector toward the investment sector until nominal wage rates are equalized across sectors (i.e. $W_{c,t} = W_{i,t} = W_t$). Hence, hours worked in the consumption sector move countercyclically, and the general co-movement problem that most multi-sector neoclassical models experience arises. In contrast, if hours worked are not perfect substitutes, workers are reluctant to substitute labor across sectors. Thus, nominal wage rates will not be equalized across sectors, and the relative wage in the consumption sector remains low. This low relative wage in the consumption sector makes consumption-good producing firms demand more labor, which mitigates the co-movement problem.

To derive the condition for the sectoral labor co-movement, we log-linearize (11) around steady state and obtain

$$\left(1 + \frac{1}{\theta}\right)\widehat{N}_{c,t} = \left(\frac{1}{\theta} + \omega_N - \frac{1}{\eta}\right)\widehat{N}_t, \tag{12}$$

where $\omega_N = (1 - \sigma)\left(\frac{N}{N_c}\right)^{\frac{1}{\theta}+1} \frac{W_c N_c}{P_c C}$. Note that (12) holds for all t. Therefore, our model displays sectoral labor co-movement without preferences exhibiting no wealth effects on the labor supply or intermediate goods sectors exhibiting the cost complementarity, if the following condition holds

$$\frac{1}{\theta} > -\omega_N + \frac{1}{\eta}. \tag{13}$$

In contrast, when preferences are additively separable and labor is perfectly mobile (i.e., $\omega_N = 0$ and $\theta = \infty$), which most neoclassical business cycle models assume, this condition does not hold. As discussed above, labor hours in the consumption sector move in the opposite direction of aggregate hours in this case. Again, this is the general co-movement problem that has a lot of attention in the

[3]The expression for W_t is obtained from using the following two conditions: $W_t N_t = W_{c,t}N_{c,t} + W_{i,t}N_{i,t}$, and $\frac{W_{c,t}}{W_{i,t}} = \left(\frac{N_{c,t}}{N_{i,t}}\right)^{\frac{1}{\theta}}$.

literature. The condition, (13) has some interesting implications that deserve further comments.

First, notice that (13) is obtained by using a temporal equilibrium condition. In other words, we derive it using the current market clearing condition for the labor. Hence, (13) guarantees a sectoral co-movement of labor in response to a change in expectation about future fundamentals, irrespective of whether it is correctly forecasted or whether it is based on false perceptions. Further, since (13) does not depend on the nature of shocks, it is not specific to the case of a news shock. (13) ensures a sectoral co-movement in response to any type of shocks that might be a source of business cycles, including the contemporaneous aggregate TFP shock and the sectoral TFP shocks.

Second, the non-separability in itself does not generate the sectoral employment co-movement without imperfect labor mobility. The reason is that the condition for the model to generate the co-movement when there is perfect labor mobility violates the normality of consumption and leisure. To see this, note that when $\theta \to \infty$, (13) reduces to

$$-\omega_N + \frac{1}{\eta} < 0.$$

This condition contradicts the normality of consumption and leisure.

Third, even though the non-separability alone cannot contribute to the co-movement, it expands the threshold level of the intratemporal elasticity of labor supply, θ, needed for generating the sectoral employment co-movement.

Fourth, when the intertemporal elasticity of aggregate labor supply (the Frisch elasticity) is equal to the intratemporal elasticity of labor supply (i.e., $\eta = \theta$), $v(N_t)$ takes the form of $v(N_t) = N_{c,t}^{\frac{\theta+1}{\theta}} + N_{i,t}^{\frac{\theta+1}{\theta}}$. This effectively isolates each sector's labor supply pool, which insulates sectors from rising costs in other areas of the economy. In this case, it is essential to have the non-separability in consumption and labor supply for the model to generate the co-movement. The economic intuition is simple: The non-separability in consumption and leisure implies that consumption and aggregate labor are complements, so that it is likely that hours worked in the consumption sector move together with aggregate hours worked. This special case is particularly important because, as will be discussed later, the empirical evidence suggests that $\eta \approx \theta$.

Finally, it should be noted that while (13) would produce the employment co-movement, it is silent about whether it would guarantee the "right" co-movement. If aggregate labor falls in response to a positive news shock because of wealth effects, then (13) would imply the co-movement of the wrong kind: it would imply a drop in employment in the consumption sector and thus consumption as well! In the simulations below, we show that investment adjustment costs induce substitution effects, which increase aggregate labor and investment on receipt of a positive news shock, so that (13) generates the "right" co-movement in our model.

4 Simulations

In this section, we simulate our model to show that our model successfully generates the sectoral co-movement. We provide insights into the underlying mechanism, through which each element in our model contributes to our model's success in generating the co-movement. We also study the robustness of our quantitative results.

4.1 Parameter Values

To be comparable, we adapt the following parameter values used in Jaimovich and Rebelo (2009) for our benchmark model. We set the discount factor (β) to 0.985, and the capital share (α) to 0.36. We assume that the steady-state depreciation rate at the steady state is the same across sectors and set to 0.025. We choose the second derivative of the investment-adjustment costs function evaluated at the steady state, $\phi_K''(1)$, to equal 1.3. We assume that the elasticity of $\delta'(\cdot)$ evaluated in the steady state ($\kappa \equiv \delta''(u_j)u_j/\delta'(u_j)$, where u_j is the level of utilization in the sector $j = c, i$ in the steady state) is the same across sectors and is set to 0.15. Because there is little guidance in the literature about appropriate values for $\phi''(1)$ and $\kappa = \delta''(u)u/\delta'(u)$, we discuss below the robustness of our results to these parameters.

Following Basu and Kimball (2002), we set the intertemporal elasticity of substitution in consumption (σ) to 0.5, which implies that consumption and labor are complements in the utility function. Using the same utility function as (2), Basu and Kimball (2002) show that the data reject additively separable preferences and the estimated elasticity of intertemporal substitution is around 0.5. The parameter θ, which determines the elasticity of substitution between hours worked in different sectors, is set to one based on the empirical work by Horvath (2000). He uses the fact that relative labor hour percentage changes in one sector are related to relative labor's share percentage changes in that sector by the elasticity $\theta/(\theta+1)$.[4] He estimates this elasticity from an Ordinary Least Square regression of the change in the relative labor supply on the change in the relative labor share using sectoral U.S. data and finds $\theta = 0.9996$ with standard error of 0.0027. We set Frisch elasticity of aggregate labor supply (η) to 1. This value is a lower bound on the Frisch elasticity used in the literature.[5] Finally, we assume that the ratio of consumption to investment in the steady state is 3.

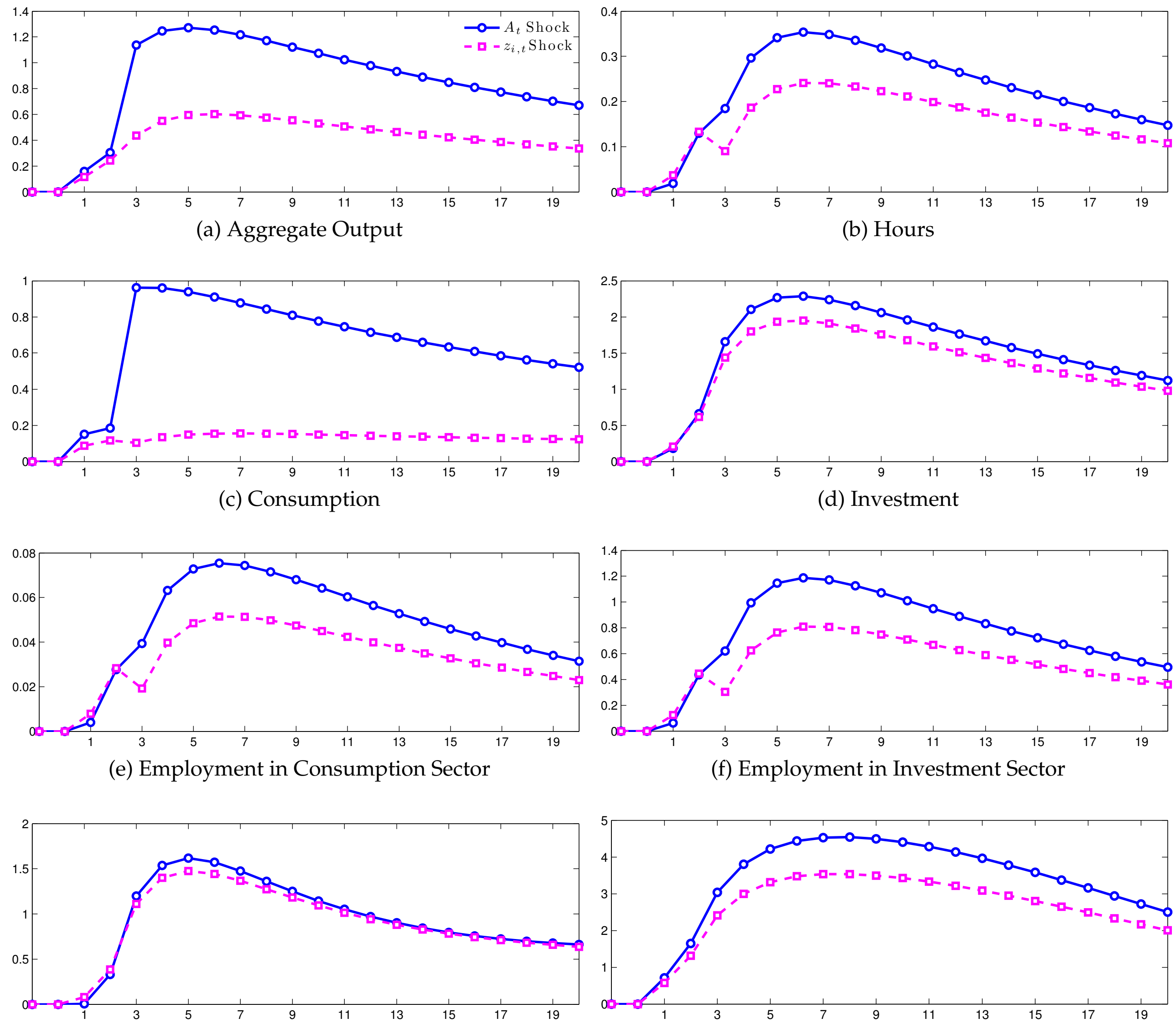
4.2 Results

Here we present simulations of the model. The timing of the news shock we consider is as follows. At time zero, the economy is in the steady state. At time one, unanticipated news arrives. Agents learn that there will be a one-percent temporary increase in A_t or $z_{i,t}$ beginning two periods later, in period three (i.e., $p = 3$) with a persistent parameter ρ equal to 0.95. Figure 1 depicts the responses of the economy to this news shock. There is an expansion in periods one and two in response to both positive news about aggregate TFP (A_t) and sectoral TFP in the investment sector ($z_{i,t}$). Output, employment and investment in the consumption and investment sectors rise together in periods one and two, even though the positive shock only materializes in period three. Therefore, our model successfully produces the business cycle co-movement in response to news about future values of A_t and $z_{i,t}$.

Furthermore, in our model, output, employment, and investment in the consumption and investment sectors continue to move together even after the shock is materialized (in period three). This implies that our model can also generate the sectoral co-movement in those variables in response to contemporaneous aggregate TFP shocks and sectoral shocks to TFP in the investment sector. Figure 2 depicts the responses of our model economy to a temporary, contemporaneous one-percent shock to A_t or $z_{i,t}$. Figure 2 confirms that our model also generates the sectoral co-movement in response to these two contemporaneous shocks. This is another important contribution of our paper because it has been considered difficult for a standard two-sector neoclassical model to generate the sectoral co-movement of investment and hours worked in response to contemporaneous aggregate

[4]To see this relationship, recall that $\frac{W_{c,t}}{W_t} = \left(\frac{N_{c,t}}{N_t}\right)^{\frac{1}{\theta}}$. Multiplying both sides by $N_{c,t}/N_t$, the elasticity of the relative labor hours in the consumption sector, $N_{c,t}/N_t$, with respect to the relative labor share, $W_{c,t}N_{c,t}/W_tN_t$, is given by $\theta/(\theta+1)$.

[5]Note that Jaimovich and Rebelo (2009) assume a relatively elastic labor supply. They set η to 2.5. As (13) shows, setting η to 2.5 would be favorable to our results because it would expand the range of θ consistent with sectoral labor co-movement.



(a) Aggregate Output (b) Hours (c) Consumption (d) Investment (e) Employment in Consumption Sector (f) Employment in Investment Sector (g) Investment to Consumption Sector (h) Investment to Investment Sector

Figure 1: Responses to the News about A_t and $z_{i,t}$

Note: Horizontal axes take model periods and vertical axes measure percentage deviations from the steady-state values. Solid lines and dashed lines represent responses to a 1-percentage increase in A_t and $z_{i,t}$, respectively at period three.

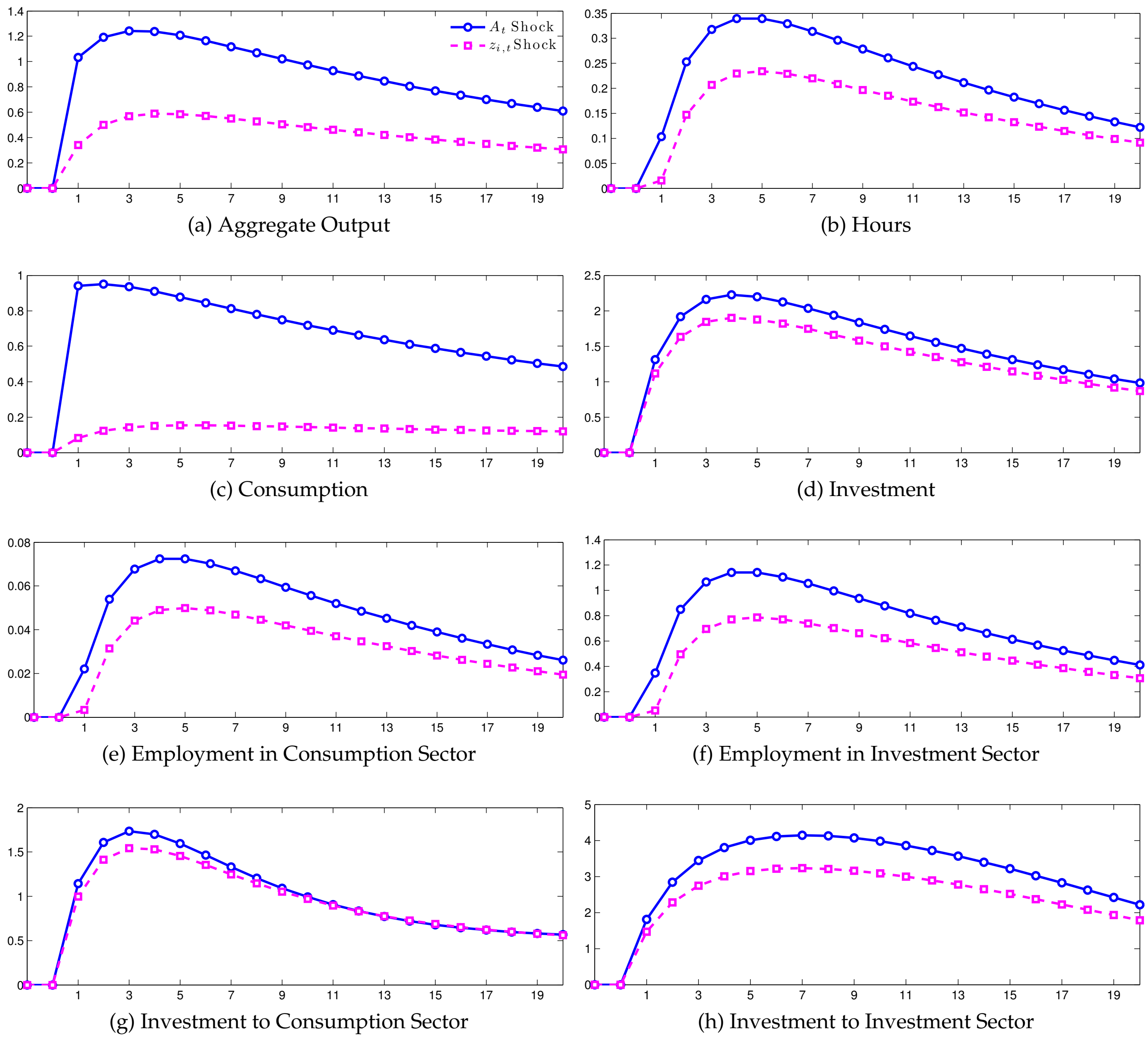
TFP shocks. Christiano and Fitzgerald (1998) suggest several modifications to generate the sectoral co-movement in response to contemporaneous aggregate TFP shocks. However, the elements in our model are outside the set of specifications that they consider.

4.3 Anatomy of the model

We now illustrate the role played by the four features of our model – investment adjustment costs, variable capital utilization, frictions in labor mobility, and non-separable preferences – in generating the business cycle sectoral co-movement in response to good news about future productivity. Toward this end, let us start considering a standard two-sector RBC model, where all of these features are shut down. We will then introduce each feature of our model to this standard RBC model one by one.

Figure 3 shows the responses of the economy to a positive news shock in a standard two-sector RBC model. On receipt of a positive new shock, consumption rises, but aggregate investment and labor decline. The good news about future productivity induces a strong wealth effect, increasing consumption and leisure at the expense of aggregate investment. To meet the increase in the demand for consumption goods, productive resources must be shifted out of the production of investment goods into the production of consumption goods. Because of this, $N_{c,t}$ in period one and two and $I_{c,t}$ in period one rise, but $N_{i,t}$ in period one and two and $I_{i,t}$ in period one fall.

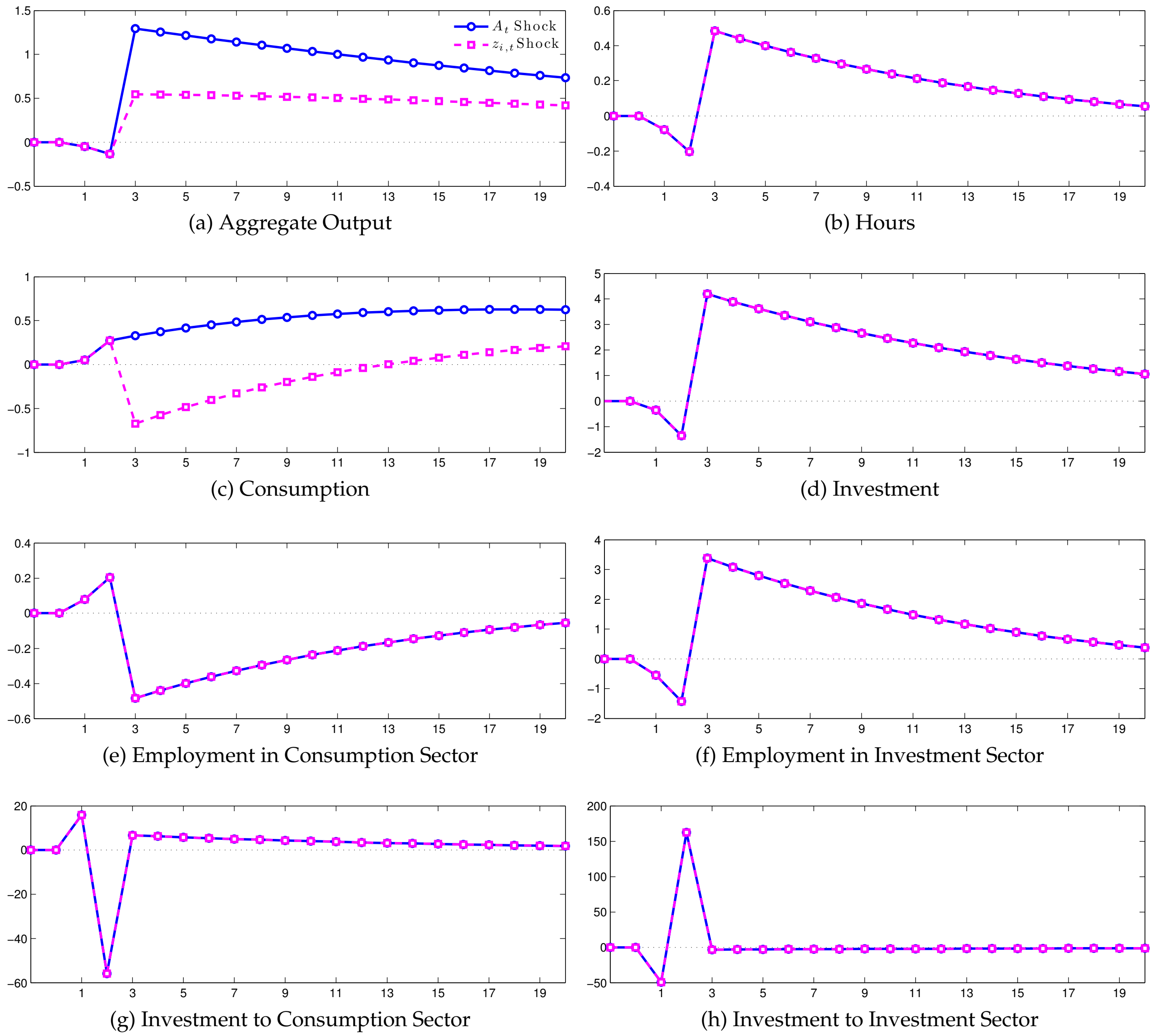
We then introduce investment adjustment costs to the two-sector RBC model, leaving other features of our model shut down. Figure 4 displays the responses of the economy to the positive news shock only with the investment adjustment costs. While consumption declines following the positive news shock, adjustment costs to investment in each sector generate a positive response in aggregate hours worked and investment. As Jaimovich and Rebelo (2009) clearly explain, adjustment costs to investment make it optimal to smooth investment over time and thus provide a reduced-form representation of the economic mechanism that would operate immediately in response to the positive news shock. With high enough adjustment costs, the intertemporal substitution effect might dominate the wealth effect, so that aggregate hours worked and investment might rise in response to the positive news shock. In fact, this is exactly what is happening in Figure 4 and they respond positively to the news shocks in the first two periods. However, the sectoral co-movement



(a) Aggregate Output
(b) Hours
(c) Consumption
(d) Investment
(e) Employment in Consumption Sector
(f) Employment in Investment Sector
(g) Investment to Consumption Sector
(h) Investment to Investment Sector

Figure 2: Responses to A_t and $z_{i,t}$ Contemporaneous Shocks

Note: Horizontal axes take model periods and vertical axes measure percentage deviations from the steady-state values. Solid lines and dashed lines represent responses to an immediate 1-percentage increase in A_t and $z_{i,t}$, respectively at period one.



(a) Aggregate Output (b) Hours

(c) Consumption (d) Investment

(e) Employment in Consumption Sector (f) Employment in Investment Sector

(g) Investment to Consumption Sector (h) Investment to Investment Sector

Figure 3: Responses to A_t and $z_{i,t}$ News Shocks in the Standard Two-Sector RBC Model

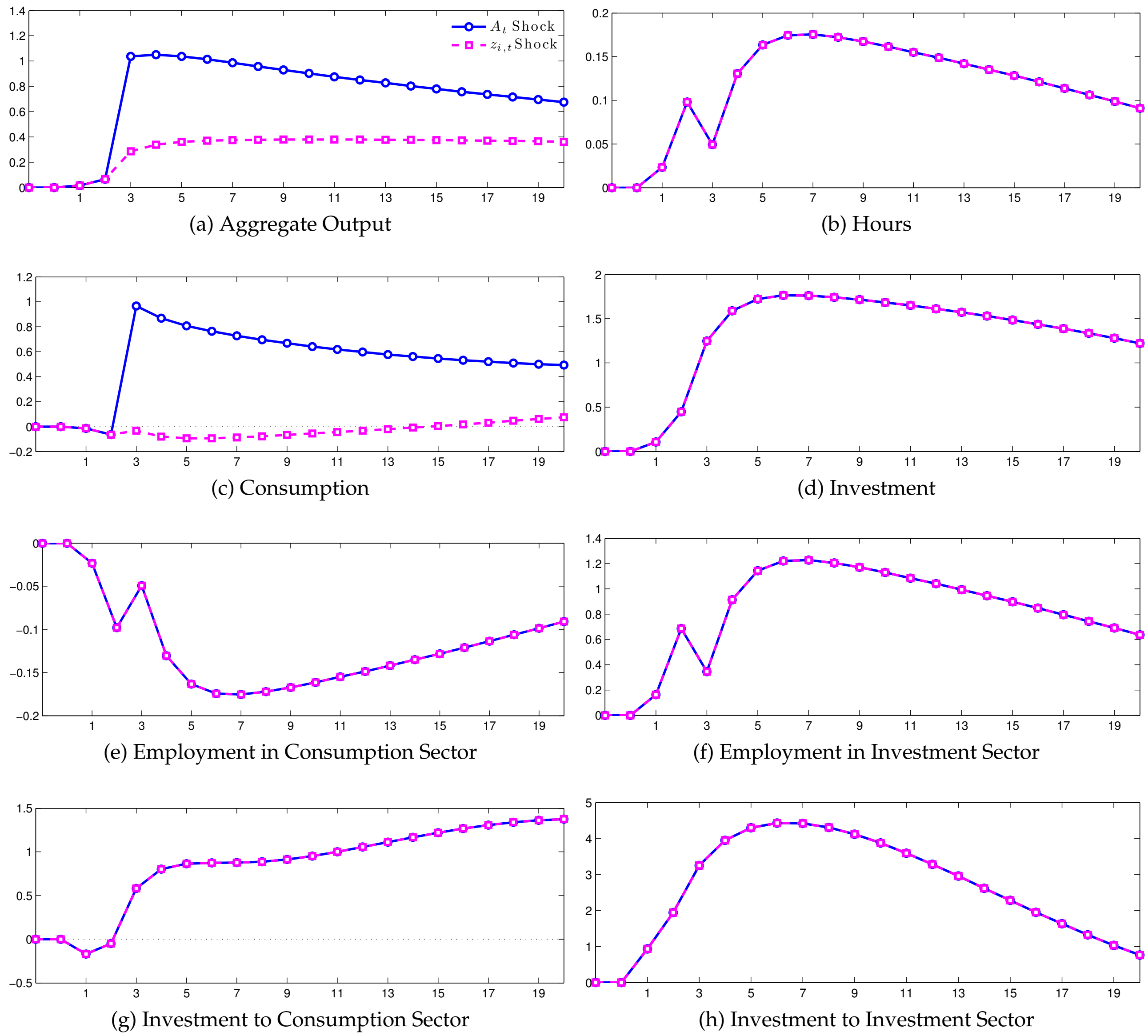
Note: Horizontal axes take model periods and vertical axes measure percentage deviations from the steady-state values. Solid lines and dashed lines represent responses to a 1-percentage increase in A_t and $z_{i,t}$, respectively at period three. These impulse response functions are obtained from the standard two-sector RBC model.

problem still exists. That is, hours worked and investment in each sector move in the opposite direction. However, adjustment costs to investment in each sector seem to alleviate the problem of sectoral co-movement in investment. Even though $I_{c,t}$ and $I_{i,t}$ do not move together in response to the news shock, the difference between these two is substantially reduced compared to the standard RBC model.

In addition to the investment adjustment costs, we now allow the rate of capital utilization in each sector to vary, maintaining the assumption of perfect labor mobility and separable preferences. Figure 5 depicts the responses of the economy with the investment adjustment costs and the variable capital utilization. The most significant change in the reaction of the economy is that the variable capital utilization combined with the investment adjustment costs generates the co-movement in sectoral investment. Both $I_{c,t}$ and $I_{i,t}$ rise in response to the positive news shock. However, the investment adjustment costs and the variable capital utilization do not solve the problem of co-movement in hours worked across consumption and investment sectors. $N_{c,t}$ and $N_{i,t}$ still move in the opposite direction. Further, even though the variable capital utilization induces a positive response in consumption in period one, consumption falls in period two and yet aggregate investment increases in periods one and two. Hence, the model still fails to generate the strong co-movement in output across two sectors.

Along with variable capital utilization and investment adjustment costs, frictions in labor reallocation are now introduced, maintaining the separable preferences. Figure 6 portrays the responses of the economy with the separable preferences. It clearly shows that frictions in labor mobility significantly alleviate the problem of co-movement in hours worked across sectors. $N_{c,t}$ has declined before frictions in labor mobility are introduced, but now it does not respond to a positive news shock. This invariant response of hours worked in the consumptions sector is already anticipated by (13). Given our parameterization that $\theta = \eta = 1$ and $\sigma = 1$, (13) implies that $N_{c,t}$ does not change in response to the news shock. Due to this acyclical response of $N_{c,t}$, consumption in period two does not fall any longer and stays the same as in period one.

Finally, the feature of our model that we have not considered thus far is the non-separability between consumption and labor in the utility function. To understand the role of non-separable preferences, let us compare the responses of our model economy with (Figure 1) and without (Figure 6) non-separability. It is straightforward to see that the non-separability enables the model



(a) Aggregate Output (b) Hours

(c) Consumption (d) Investment

(e) Employment in Consumption Sector (f) Employment in Investment Sector

(g) Investment to Consumption Sector (h) Investment to Investment Sector

Figure 4: Responses to A_t and $z_{i,t}$ News Shocks with Investment Adjustment Costs

Note: Horizontal axes take model periods and vertical axes measure percentage deviations from the steady-state values. Solid lines and dashed lines represent responses to a 1-percentage increase in A_t and $z_{i,t}$, respectively at period 3. These impulse response functions are obtained when investment adjustment costs are introduced to the standard two-sector RBC model.

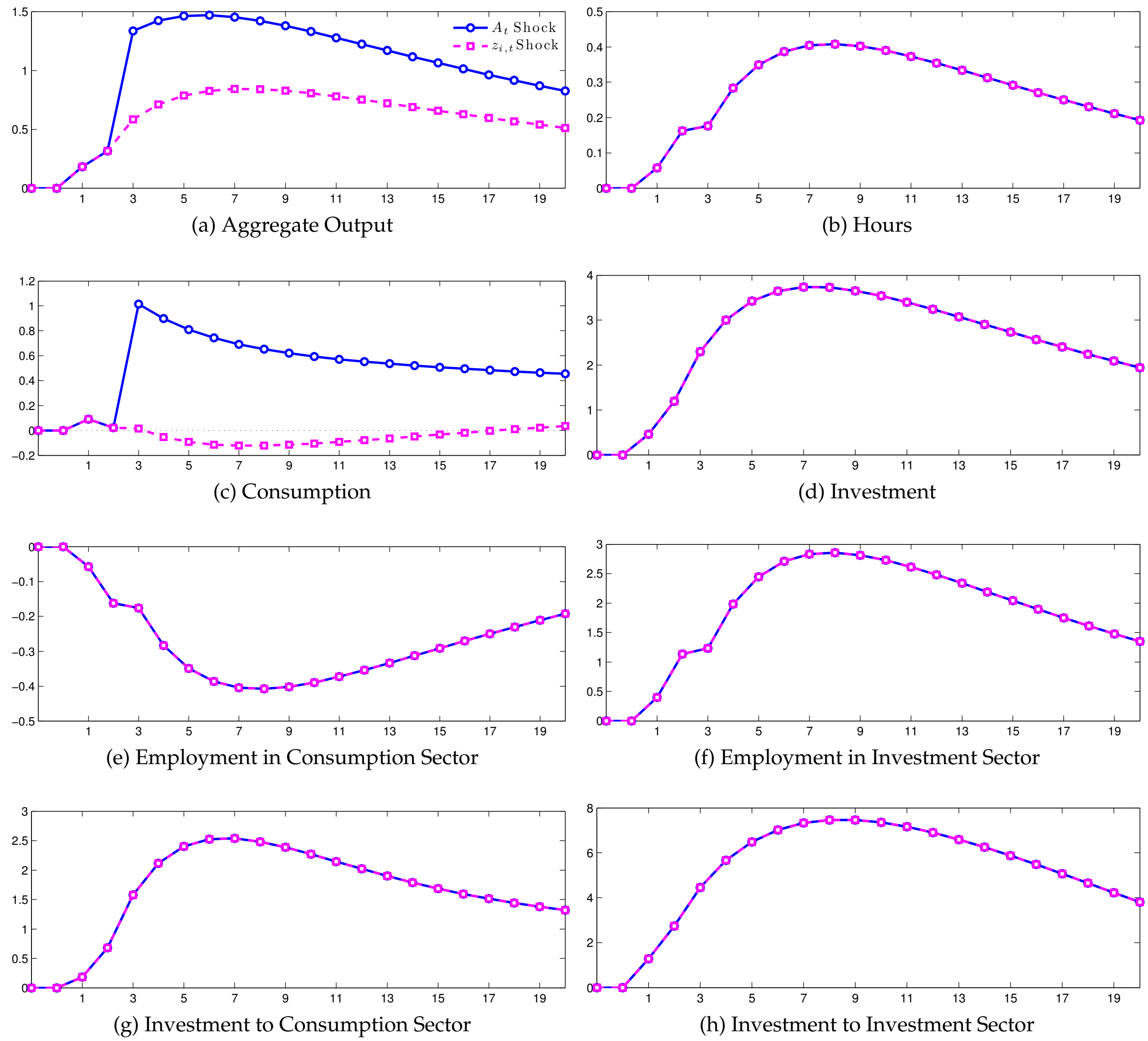
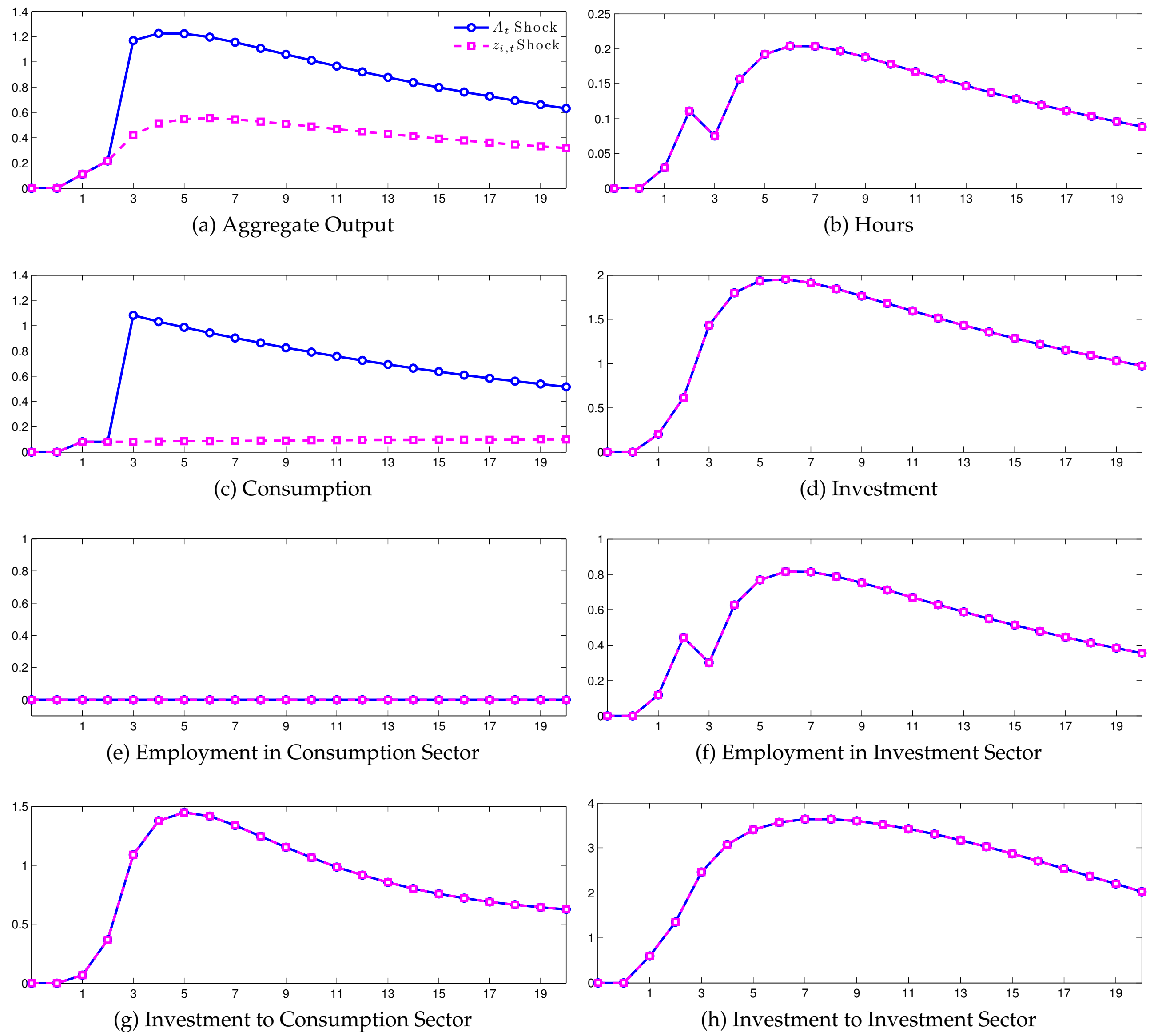


Figure 5: Responses to A_t and $z_{i,t}$ News Shocks with Investment Adjustment Costs and Variable Capital Utilization

Note: Horizontal axes take model periods and vertical axes measure percentage deviations from the steady-state values. Solid lines and dashed lines represent responses to a 1-percentage increase in A_t and $z_{i,t}$, respectively at period 3. These impulse response functions are obtained when investment adjustment costs and the variable capital utilization are introduced.



(a) Aggregate Output (b) Hours (c) Consumption (d) Investment (e) Employment in Consumption Sector (f) Employment in Investment Sector (g) Investment to Consumption Sector (h) Investment to Investment Sector

Figure 6: Responses to A_t and $z_{i,t}$ News Shocks with Investment Adjustment Costs, Variable Capital Utilization, and Limited Labor Mobility

Note: Horizontal axes take model periods and vertical axes measure percentage deviations from the steady-state values. Solid lines and dashed lines represent responses to a 1-percentage increase in A_t and $z_{i,t}$, respectively at period three. These impulse response functions are obtained when investment adjustment costs, variable capital utilization and frictions in labor reallocation are introduced.

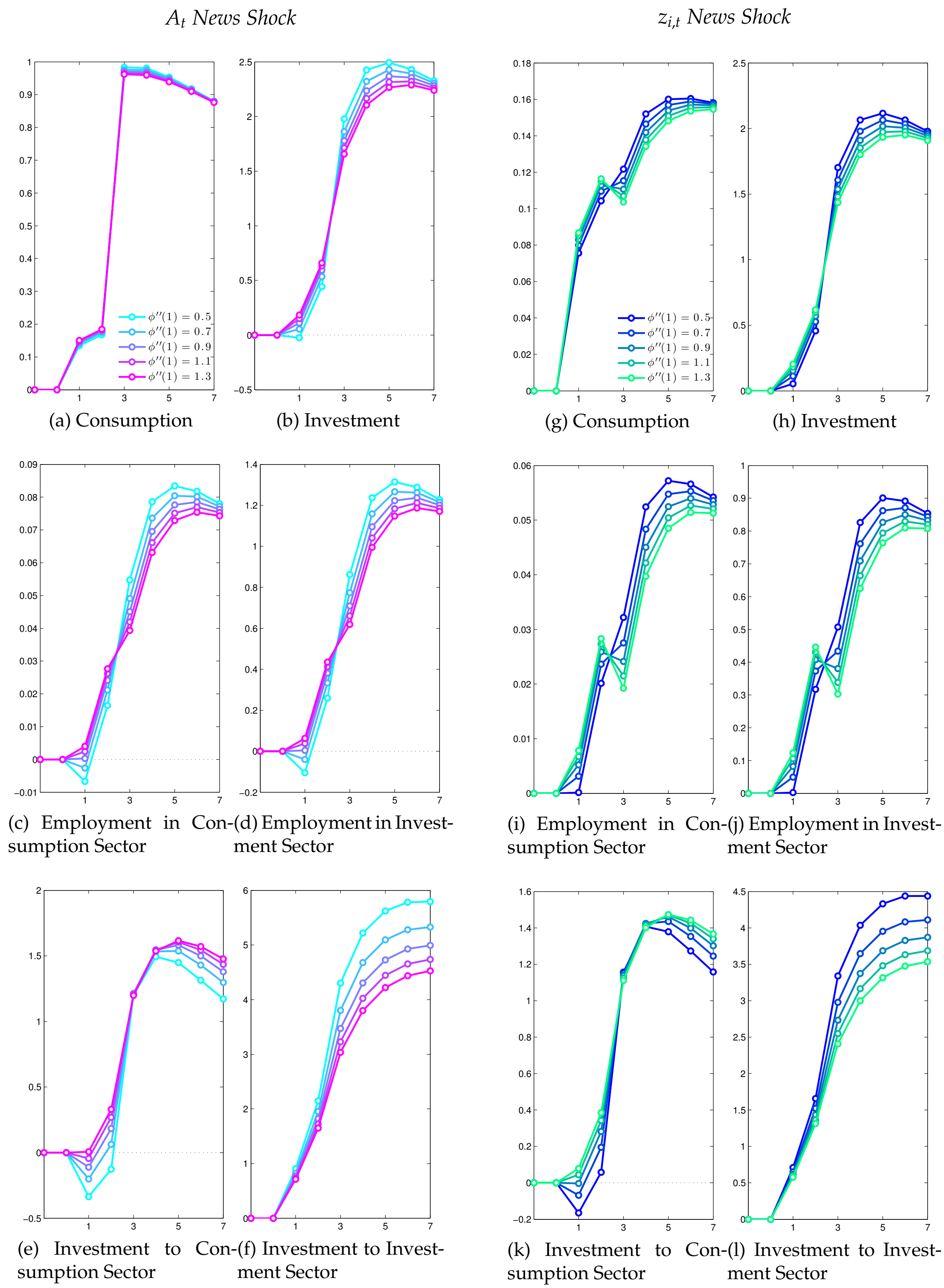
to generate a positive response in hours worked in the consumption sector and consumption in periods one and two. Under our calibration that $\theta = \eta = 1$, therefore, non-separable preferences play an important role in generating the co-movement in output and hours worked across sectors. As discussed before, this is due to the fact that the non-separable preferences imply the complementarity between consumption and aggregate hours worked. When hours worked increase, agents also wish to increase their consumption, implying that labor in the consumption sector also increases.

4.4 Robustness

We study the sensitivity of our quantitative results to variations in $\phi^{''}(1)$ and $\kappa \equiv \frac{\delta^{''}(u)u}{\delta^{'}(u)}$, since there is little guidance in the literature about appropriate values for these parameters. We use our benchmark calibration and change the values of $\phi^{''}(1)$ and κ one by one.

Figure 7 portrays the responses of the economy to the positive news shock in A_t and $z_{i,t}$ with different values of $\phi''(1)$. The left two columns of Figure 7 represent responses to the A_t news shock and the right two columns of Figure 7 correspond to results with the $z_{i,t}$ news shock. As the figure shows, if the size of the investment adjustment costs are not large enough, the model fails to generate the sectoral co-movement in investment and results in the "wrong" kind of sectoral co-movement in labor. While moderate investment adjustment costs can produce the sectoral co-movement in response to news about $z_{i,t}$ ($\phi''(1) > 0.9$), non-negligible investment adjustment costs are necessary to obtain the sectoral co-movement in response to news about A_t ($\phi''(1) > 1.3$).

Figure 8 displays how the economy reacts to the news shocks with different values of κ. As the figure shows, varying κ does not significantly affect the ability of the model to generate the sectoral co-movement in labor, but it does its ability to generate the sectoral co-movement in investment. To obtain the sectoral co-movement in response to A_t news shock, the elasticity of the cost of utilization with respect to the rate of utilization needs to be relatively low ($\kappa < 0.15$), implying that varying utilization does not induce a significant cost. In contrast, our model generates the sectoral co-movement in response to $z_{i,t}$ news shock in a broader range of κ, implying that varying utilization can be relatively costly.



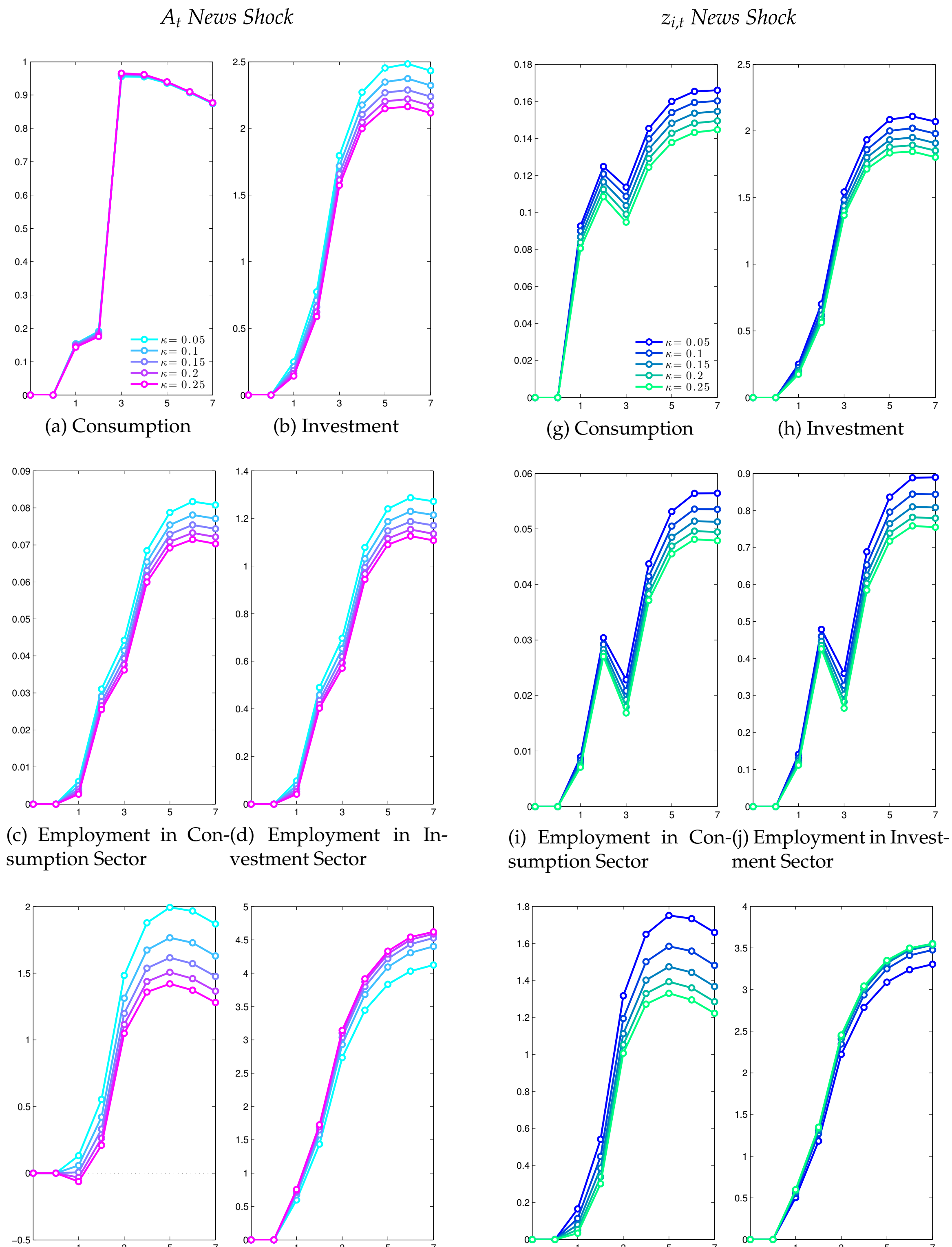
(a) Consumption (b) Investment (g) Consumption (h) Investment

(c) Employment in Consumption Sector (d) Employment in Investment Sector (i) Employment in Consumption Sector (j) Employment in Investment Sector

(e) Investment to Consumption Sector (f) Investment to Investment Sector (k) Investment to Consumption Sector (l) Investment to Investment Sector

Figure 7: Responses to News Shocks with Various Values of $\phi''(1)$

Note: Horizontal axes take model periods and vertical axes measure percentage deviations from the steady-state values. Those lines represent responses to a 1-percentage increase in A_t or $z_{i,t}$ at period three with different values of $\phi''(1)$. Left two columns depict responses to the A_t news shock and right two columns are those to the $z_{i,t}$ news shock.



(a) Consumption (b) Investment (g) Consumption (h) Investment

(c) Employment in Consumption Sector (d) Employment in Investment Sector (i) Employment in Consumption Sector (j) Employment in Investment Sector

(e) Investment to Consumption Sector (f) Investment to Investment Sector (k) Investment to Consumption Sector (l) Investment to Investment Sector

Figure 8: Responses to News Shocks with Various Values of $\kappa = \frac{\delta''(u)u}{\delta'(u)}$

Note: Horizontal axes take model periods and vertical axes measure percentage deviations from the steady-state values. Those lines represent responses to a 1-percentage increase in A_t or $z_{i,t}$ at period three with different values of $\kappa = \frac{\delta''(u)u}{\delta'(u)}$. The left two columns depict responses to the A_t news shock and the right two columns are those to the $z_{i,t}$ news shock.

4.5 Caveat

While our model generates the business cycle co-movement in response to positive news about the aggregate TFP (A_t) and the sectoral TFP in the investment sector ($z_{i,t}$), it also has some anomalies. Our model fails to generate the co-movement in response to positive news about sectoral TFP in the consumption sector ($z_{c,t}$). Figure 9 depicts the responses of our model economy to the positive news about $z_{c,t}$ with the same timing and persistence of the shock as before. For the case of the news shock about $z_{c,t}$, the intertemporal substitution effect due to investment adjustment costs seems to be dominated by the wealth effect of the news shock. Therefore, aggregate hours worked and investment fall in response to the positive news about $z_{c,t}$ even in the presence of investment adjustment costs. Because of the decline in aggregate hours worked, (13) implies that our model produces the sectoral co-movement of hours worked, but of the wrong kind: both $N_{c,t}$ and $N_{i,t}$ fall in response to the positive news shock $z_{c,t}$.

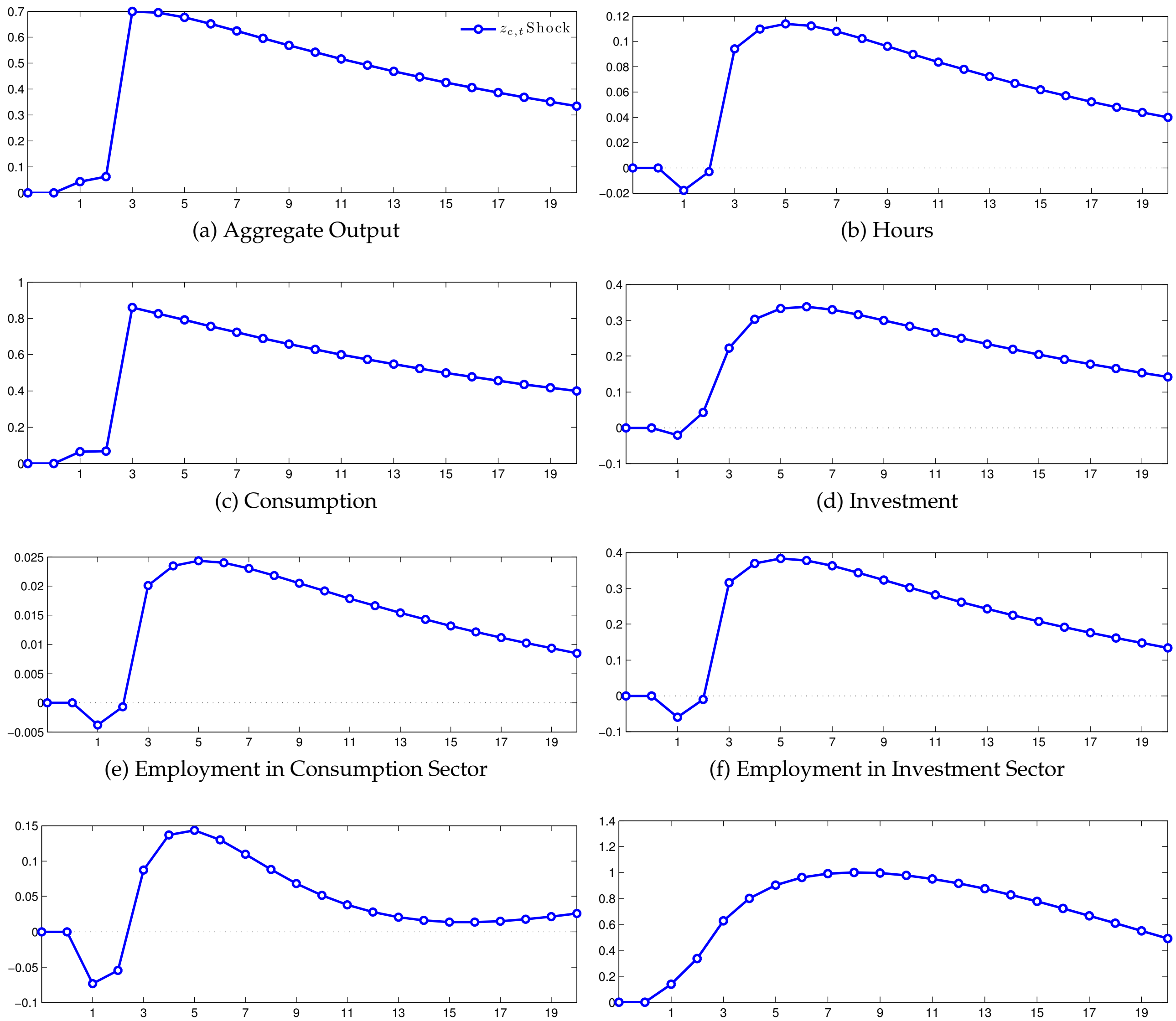
Below, we demonstrate that this anomaly disappears once we introduce consumer durable goods into the utility function, with adjustment costs in purchasing consumer durable goods.

5 Estimation

In this section, we estimate the key parameters of our model that characterize the sectoral co-movement. In doing so, we employ a Bayesian approach. We first start with the two-sector model presented in Section 2. We then present the estimated results supporting for the co-movement condition analyzed in Section 3. We also estimate the two-sector version of Jaimovich and Rebelo (2009). Then, by using the Bayes factor, we compare our model against their model.

In order to incorporate sectoral characteristics into the estimation, we shall utilize sector-specific data, rather than the aggregate data. Here we will use the following six observables: the real per capita consumption growth dC_t, the real wage growth rate in consumption sector $dw_{c,t}$, the log average hours worked in consumption sector $h_{c,t}$, the real per capita investment growth dI_t, the real wage growth rate in consumption sector $dw_{i,t}$, and the log average hours worked in consumption sector $h_{i,t}$.[6] Sectoral labor data are constructed from the Current Employment Statistics of the BLS.

[6]We assume that the consumption sector consists of firms producing non-durable goods and services and that the investment sector produces goods used for non-residential investment and residential investment.



(a) Aggregate Output

(b) Hours

(c) Consumption

(d) Investment

(e) Employment in Consumption Sector

(f) Employment in Investment Sector

(g) Investment to Consumption Sector

(h) Investment to Investment Sector

Figure 9: Responses to $z_{c,t}$ News Shocks

Note: Horizontal axes take model periods and vertical axes measure percentage deviations from the steady-state values. Solid lines represent responses to a 1-percentage increase in $z_{c,t}$ at period 3. These impulse response functions are obtained from the benchmark model.

The Appendix describes the data construction in detail. The sample period starts from 1984:I and ends at 2010:IV. All variables are demeaned before the estimation.

In a state-space representation, the following measurement equations link the observables to the model counterparts.

$$dC_t = \widehat{C}_t - \widehat{C}_{t-1} \tag{14}$$

$$dw_{c,t} = \widehat{w}_{c,t} - \widehat{w}_{c,t-1} \tag{15}$$

$$h_{c,t} = \widehat{N}_{c,t} \tag{16}$$

$$dI_t = \widehat{I}_t - \widehat{I}_{t-1} \tag{17}$$

$$dw_{i,t} = \widehat{w}_{i,t} - \widehat{w}_{i,t-1} + e_t \tag{18}$$

$$h_{i,t} = \widehat{N}_{i,t} \tag{19}$$

Note that the real wage growth in the investment sector is subject to a measurement error $e_t \sim N(0, \sigma_e^2)$. We believe this formulation is important for a couple of reasons. First, contrary to the underlying assumptions in the model, the industry-level wage data show a divergent pattern between two sectors over the sample period as discussed by Iacoviello and Neri (2010). Second, even though we have a nice prediction on the co-movement in the sectoral labor, the link is too tight. That is, the sectoral labor and wage ratios must move proportionally. This appears to be too much restrictions and we need to relax this link in order to obtain reasonable estimation results. This formulation is equivalent to including the measurement error in the real wage growth in the consumption sector. That is, we are adding a measurement error to the ratio of real wages in the two sectors.

As in Fujiwara, Hirose, and Shintani (2011) and Schmitt-Grohé and Uribe (2008), we model the information structure on the contemporaneous and anticipated shocks in the following way. The aggregate and sector-specific technology shocks are assumed to follow

$$\widehat{A}_t = \rho_a \widehat{A}_{t-1} + v^0_{a,t} + v^1_{a,t-1} + v^2_{a,t-2} + v^3_{a,t-3} + v^4_{a,t-4}$$

$$\widehat{z}_{c,t} = \rho_c \widehat{z}_{c,t-1} + v^0_{c,t} + v^1_{c,t-1} + v^2_{c,t-2} + v^3_{c,t-3} + v^4_{c,t-4}$$

$$\widehat{z}_{i,t} = \rho_i \widehat{z}_{i,t-1} + v^0_{i,t} + v^1_{i,t-1} + v^2_{i,t-2} + v^3_{i,t-3} + v^4_{i,t-4}$$

where $v_{j,t}^h \sim N(0, (\sigma_j^h)^2)$ for $h = 0, 1, \cdots, 4$ and $j = \{a, c, i\}$. $v_{j,t}^0$ for $j = \{a, c, i\}$ denote the unanticipated contemporaneous shocks and $v_{j,t}^h$ for $h = 1, \cdots, 4$ represent the h-period-ahead news shock anticipated at time $t - h$. Here we assume that the agents receive the news up to four periods.

We fix some of the model parameters. As in Section 4.1, We set the discount factor (β) to 0.985, and the capital share (α) to 0.36. We assume that the steady-state depreciation rate at the steady state is the same across sectors and set to 0.025. The ratio of consumption to investment in the steady state is fixed to 3. All of these values are consistent with the values used in Jaimovich and Rebelo (2009).

We use the following prior distributions that are summarized in the left side of Table 1. For the structural parameters, we mostly follow the prior distributions used in Schmitt-Grohé and Uribe (2010). Exceptions are $1/\eta$, $1/\theta$, and $1/\sigma$. As in Iacoviello and Neri (2010), we use a Gamma distribution for $1/\eta$ with mean 0.5 and standard deviation of 0.1. Similarly, we assume a Normal distribution for $1/\theta$ with mean 1 and standard deviation of 0.1. This choice of the prior mean is consistent with the estimate of Horvath (2000). Finally, we use a Normal distribution for $1/\sigma$ with mean 3 and standard deviation of 0.5. This is motivated by the posterior distribution obtained in the two-sector model of Kim and Katayama (2010). This prior mean of the non-separability parameter is also consistent with the one found in Guerron-Quintana (2008).

For the standard deviations of exogenous shocks in the model, we use Gamma distributions. As discussed in Schmitt-Grohé and Uribe (2010), this choice imposes a conservative stance on the importance of anticipated shocks. It is because, unlike the typical Inverse Gamma distributions, the Gamma distribution allows a positive density at zero. That is, our prior incorporates a possibility that the anticipated shocks are not operating. Furthermore, we impose the 75-percent rule on the prior means of the standard deviations of the anticipated shocks. That is, we restrict the variance of the unanticipated shock accounts for 75 percent of the total variance of the shock and we assume that the four types of anticipated shocks are equally important to account for the remaining portion of the total variance. Our choice of priors are more conservative than those used in Fujiwara, Hirose, and Shintani (2011), which use equal weights on anticipated and contemporaneous components, in terms of the role of the anticipated shocks.

We numerically find the posterior mode and use it as a starting point of the random-walk Metropolis-Hastings algorithm. The subsequent results are all based on 300,000 Metropolis-Hastings

Table 1: Prior and Posterior Distributions for the Benchmark Model

Parameter	Prior Distribution			Posterior Distribution		
	Distribution	Mean	Std. Dev.	Mean	5 %	95 %
$\kappa_c = \kappa_i$	Inv. Gamma	1	1	0.3181	0.2515	0.3870
$\phi''(1)$	Gamma	4	1	1.9880	1.5505	2.4084
$1/\eta$	Gamma	0.5	0.1	0.1010	0.0977	0.1059
$1/\theta$	Normal	1	0.1	0.4016	0.3639	0.4317
$1/\sigma$	Normal	3	0.5	6.0582	5.8917	6.1807
ρ_a	Beta	0.7	0.2	0.9318	0.9118	0.9505
ρ_c	Beta	0.7	0.2	0.9997	0.9993	1.0000
ρ_i	Beta	0.7	0.2	0.9993	0.9984	1.0000
σ_a^0	Gamma	0.015	0.015	0.0017	0.0000	0.0034
σ_a^1	Gamma	0.0043	0.0043	0.0035	0.0000	0.0073
σ_a^2	Gamma	0.0043	0.0043	0.0048	0.0000	0.0103
σ_a^3	Gamma	0.0043	0.0043	0.0048	0.0000	0.0105
σ_a^4	Gamma	0.0043	0.0043	0.0075	0.0000	0.0126
σ_c^0	Gamma	0.015	0.015	0.0013	0.0000	0.0026
σ_c^1	Gamma	0.0043	0.0043	0.0041	0.0000	0.0074
σ_c^2	Gamma	0.0043	0.0043	0.0053	0.0004	0.0089
σ_c^3	Gamma	0.0043	0.0043	0.0036	0.0000	0.0068
σ_c^4	Gamma	0.0043	0.0043	0.0088	0.0065	0.0110
σ_i^0	Gamma	0.015	0.015	0.0169	0.0132	0.0205
σ_i^1	Gamma	0.0043	0.0043	0.0021	0.0000	0.0047
σ_i^2	Gamma	0.0043	0.0043	0.0052	0.0000	0.0100
σ_i^3	Gamma	0.0043	0.0043	0.0061	0.0000	0.0136
σ_i^4	Gamma	0.0043	0.0043	0.0062	0.0000	0.0121
σ_e	Gamma	0.001	0.01	0.0060	0.0053	0.0066
Log Marginal Density		1294.3066				

Note: The posterior distributions are obtained using the random walk Metropolis-Hastings algorithm with 300,000 draws (the first 10% of draws are discarded as a burn-in period). We use the modified Harmonic mean estimator of Geweke (1999) to obtain the log marginal density.

draws.[7] We adjust the scaling factor in the MetropolisHastings algorithm, such that the acceptance rate becomes about 1/3.

Table 1 reports the posterior distributions of parameters in our benchmark model presented in Section 2. Posterior means satisfy the co-movement conditions analyzed in Section 3. As a result, the sectoral employments as well as other variables show the co-movement with respect exogenous shocks, regardless of whether they are anticipated or not.

It is of our interest to see whether our proposed mechanism of generating the sectoral co-movement is supported by the data, especially against the two-sector version of the model con-

[7]The first 30,000 draws are discarded as a burn-in period.

sidered in Jaimovich and Rebelo (2009).[8] The novel feature in Jaimovich and Rebelo (2009) is to introduce a particular class of preferences that has a parameter governing the size of the wealth effect, which plays an important role in the co-movement problem according to their argument.

In particular, the Jaimovich-Rebelo preferences are given by

$$U(C_t, N_t) = \log\left(C_t - \psi N_t^{\zeta} X_t\right), \tag{20}$$

where X_t evolves according to

$$X_t = C_t^{\gamma} X_{t-1}^{1-\gamma}, \tag{21}$$

with $\gamma \in [0, 1]$, and $N_t = N_{c,t} + N_{i,t}$. Except for the preferences, the rest of the model is identical to the one presented in Section 2.

In terms of the parameters to be estimated, $\gamma \in [0, 1]$ controls the size of the wealth effect. When $\gamma = 0$, it corresponds to the preferences proposed by Greenwood, Hercowitz, and Huffman (1988). When $\gamma = 1$, the preferences collapses to the standard King-Plosser-Rebelo preferences. Note that even though the preferences considered in Section 2 builds on the King-Plosser-Rebelo preferences, our model is not nested by the Jaimovich-Rebelo preferences. A special case in our model ($\sigma = 1$ and $\theta = \infty$) coincide with a special case in the Jaimovich-Rebelo preferences ($\gamma = 1$). Following Schmitt-Grohé and Uribe (2008, 2010), we adapt a Uniform prior distribution over 0 and 1 for γ. Another parameter that is absent in our benchmark model is ζ, which controls the elasticity of labor supply. Following Schmitt-Grohé and Uribe (2008, 2010), we use a Gamma distribution with mean 4 and standard deviation of 1 as a prior distribution for ζ. The rest of the parameters are identical to the benchmark model estimated above with the same measurement equations (14)-(19).

Table 2 presents the posterior distributions of the parameters in the two-sector version of Jaimovich and Rebelo (2009). The posterior mean of γ, which controls the size of the wealth effect, is very close to 0, and this is consistent with the estimate in Schmitt-Grohé and Uribe (2010). With this value of γ, the two-sector version of Jaimovich and Rebelo (2009) also generates the sectoral co-movement.

One way of comparing two competing alternatives would be to utilize the Bayes factor. Even though our model and the model of Jaimovich and Rebelo (2009) are not nested one way or the

[8] Schmitt-Grohé and Uribe (2008, 2010) estimate the one-sector version of Jaimovich and Rebelo (2009).

Table 2: Prior and Posterior Distributions for Two-Sector Jaimovich and Rebelo (2009)

	Prior Distribution			Posterior Distribution		
Parameter	Distribution	Mean	Std. Dev.	Mean	5 %	95 %
$\kappa_c = \kappa_i$	Inv. Gamma	1	1	0.1581	0.1564	0.1595
$\phi''(1)$	Gamma	4	1	0.7150	0.5561	0.8732
γ	Uniform	0.5	0.2887	0.0610	0.0492	0.0735
ζ	Gamma	4	1	2.1361	2.0433	2.2191
ρ_a	Beta	0.7	0.2	0.9713	0.9615	0.9791
ρ_c	Beta	0.7	0.2	0.9327	0.9145	0.9513
ρ_i	Beta	0.7	0.2	0.9999	0.9997	1.0000
σ_a^0	Gamma	0.015	0.015	0.0034	0.0000	0.0071
σ_a^1	Gamma	0.0043	0.0043	0.0445	0.0378	0.0514
σ_a^2	Gamma	0.0043	0.0043	0.0033	0.0000	0.0072
σ_a^3	Gamma	0.0043	0.0043	0.0029	0.0000	0.0062
σ_a^4	Gamma	0.0043	0.0043	0.0420	0.0347	0.0495
σ_c^0	Gamma	0.015	0.015	0.0923	0.0780	0.1063
σ_c^1	Gamma	0.0043	0.0043	0.0023	0.0000	0.0051
σ_c^2	Gamma	0.0043	0.0043	0.0025	0.0000	0.0056
σ_c^3	Gamma	0.0043	0.0043	0.0047	0.0000	0.0116
σ_c^4	Gamma	0.0043	0.0043	0.0064	0.0045	0.0096
σ_i^0	Gamma	0.015	0.015	0.0160	0.0099	0.0219
σ_i^1	Gamma	0.0043	0.0043	0.0023	0.0002	0.0045
σ_i^2	Gamma	0.0043	0.0043	0.0028	0.0000	0.0044
σ_i^3	Gamma	0.0043	0.0043	0.0009	0.0000	0.0016
σ_i^4	Gamma	0.0043	0.0043	0.0621	0.0537	0.0702
σ_e	Gamma	0.001	0.01	0.0028	0.0025	0.0031
Log Marginal Density		1096.6192				

Note: The posterior distributions are obtained using the random walk Metropolis-Hastings algorithm with 300,000 draws (the first 10% of draws are discarded as a burn-in period). We use the modified Harmonic mean estimator of Geweke (1999) to obtain the log marginal density.

other, the Bayes factor shows the strength of evidence provided by the data. We use the modified Harmonic mean estimator of Geweke (1999) to obtain the log marginal density. The log data density associated with our model is 1294.3066, whereas that of Jaimovich and Rebelo (2009) is 1096.6192. In order to choose the Jaimovich-Rebelo preferences over our mechanism, we need a prior probability of the Jaimovich-Rebelo preferences $\exp(197.6874) \approx 7.15 \times 10^{85}$ times larger than that over the non-separable KPR preferences with imperfect mobility of labor. This difference seems to be extremely large and suggests that the data decisively support our model.

6 Conclusion

This paper tackles the sectoral co-movement problem in response to news shocks. We propose a two-sector model that generates the sectoral co-movement to contemporaneous and news shocks. We derive a condition for the sectoral co-movement in employment. It reveals that the key elements to the model's success are frictions in intersectoral labor mobility and non-separable preferences in consumption and leisure, together with investment adjustment costs and variable capital utilization.

More interestingly, our model produces the co-movement in response to news shocks even without assuming very small wealth effects on labor supply, strong complementarity between nondurable and durable goods, or economies of scope. While these features are shown to produce the co-movement in response to news shocks, they are typically at odds with the data. In contrast, the elements of our model are motivated by empirical plausible evidence. Furthermore, we take our model to the data to see that our proposed mechanism of generating the sectoral co-movement is supported by the data, especially against the two-sector version of the model considered in Jaimovich and Rebelo (2009). We estimate and compare two alternatives by using a Bayesian approach. It appears that the data decisively support our proposed mechanism of generating the sectoral co-movement.

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Appendix

Data Construction

$$dC_t = \Delta \log \left(\frac{\text{Non-durable (PCND)} + \text{Services (PCESV)}}{\text{GDP Deflator (GDPDEF)} \times \text{Population (POP)}} \right) \tag{22}$$

$$dI_t = \Delta \log \left(\frac{\text{Non-Residential Investment (PNFI)} + \text{Residential Investment (PRFI)}}{\text{GDP Deflator (GDPDEF)} \times \text{Population (POP)}} \right) \tag{23}$$

These data are retrieved from the FRED of the St. Louis Fed. The series IDs are in parentheses.

For the sectoral labor and wage, we use data on production and nonsupervisory employees from Tables B-6, B-7, and B-8 of the Current Employment Statistics of the BLS. We define the consumption sector as the union of non-durable and services industries and assume that the investment sector consists of construction and durable firms.[9]

The aggregation is done by the following procedures. We simply construct the total man-hours and total employment in each sector. We obtain the average hours worked in each sector by dividing the total man-hours by the total employment. Similarly, we calculate the total wage bill in each sector. We calculate the average hourly wage by taking the ratio of the total wage bill by the hours worked in each sector. The average hourly wage in each sector is deflated by using the CPI. The monthly series is converted to quarterly by taking the quarterly average.

[9] Available at http://www.bls.gov/ces/cesbtabs.htm