Comovement in Business Cycle Models: the Role of Nonseparable Preferences and Labor Market Participation *

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Abstract

Standard real business cycle models must rely on total factor productivity (TFP) shocks to explain the observed comovement between consumption, investment and hours worked (Barro and King, 1982). This paper shows that a neoclassical model with nonseparable preferences in consumption and leisure and a labor market featuring both intensive and extensive margin can generate comovement even in absence of TFP shocks. Intertemporal substitution of goods and leisure induces comovement over the business cycle through heterogeneity in consumption behavior of employed and unemployed workers. The

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result is due to two distinct mechanisms. On the one hand, individual consumption of the employed is affected by the number of hours worked, as predicted by models of home production (Becker, 1965). On the other hand, variation in the participation rate affects aggregate consumption. We calibrate and simulate the model’s response to ‘demand’ shocks such as shifts in the marginal efficiency of investment, government spending shocks and news shocks. We show that investment-specific shocks can generate business cycle fluctuations that are broadly consistent with aggregate data.

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1 Introduction

Standard real business cycle models must rely on total factor productivity (TFP) shocks to explain the observed comovement between consumption, investment and hours worked (Barro and King, 1982).

This paper shows that a neoclassical model with nonseparable preferences in consumption and leisure and a labor market featuring both intensive and extensive margin can generate comovement even in absence of TFP shocks. Intertemporal substitution of goods and leisure induces comovement over the business cycle through heterogeneity in consumption behavior of employed and unemployed workers. The result is due to two distinct mechanisms. On the one hand, individual consumption of the employed is affected by the number of hours worked, as predicted by models of home production (Becker, 1965). On the other hand, variation in the participation rate affects aggregate consumption.

We calibrate and simulate the model’s response to ‘demand’ shocks such as shifts in the marginal efficiency of investment, government spending shocks and news shocks. We show that investment-specific shocks can generate business cycle fluctuations that are broadly consistent with aggregate data.

2 The comovement problem

The standard RBC model fails to produce comovement between hours and consumption. Consider the following standard labor supply equation, derived under the assumption of separable log-utility

$$N_t^{\phi_N} = \frac{W_t}{C_t}$$

where \(\phi_N\) denoted the Frish elasticity of labor supply, or

$$\phi_N \ln N_t = \ln W_t - \ln C_t$$

$$= (1 - \alpha) \ln \frac{Y_t}{N_t} - \ln C_t.$$  

The equation shows that labor and consumption can move together if and only if the wage comoves more than proportionally with consumption. Under the assumption of perfectly competitive markets this is equivalent to requiring that labor productivity co-moves more than proportionally with
consumption. This behavior cannot be obtained under a constant labor demand. An increase in consumption has to be accompanied by a change in TFP inducing a shift in labor demand. The labor supply can thus be rearranged as

\[ [\phi_N + (1 - \alpha) \alpha] \ln N_t = (1 - \alpha) \ln TFP_t - \ln C_t + (1 - \alpha) \alpha \ln K_t \]

where capital is predetermined.

3 The model

In this section we describe the main features of our model.

**Households.** We assume that each ‘household’ is composed of a continuum of members. Labor is indivisible: each member decides whether to work (and how many hours to work) or not. Participating to the labor market entails a cost. We assume perfect risk sharing within the household. The maximization problem for the household becomes

\[
E_t \sum_{T=t}^{\infty} \beta^{T-t} \left[ e_T \left( \frac{\nu(n_T)}{1 - \sigma} \right) + (1 - e_T) \frac{\nu(0)}{1 - \sigma} - \Phi(e_T) \right], \quad \sigma > 1
\]

subject to the budget constraint

\[ C_t + \frac{I_t}{q_t} + \Phi(e_t) = R^K_t U_t K_t + W_t H_t \] (1)

and the law of capital accumulation

\[ K_{t+1} = I_t \left[ 1 - \phi \left( \frac{I_t}{I_{t-1}} \right) \right] + [1 - \delta(U_t)] K_t. \] (2)

The variable \( e_t \) denotes the fraction of the household member that is working and household consumption is defined as

\[ C_t = e_t c^e_t + (1 - e_t) c^u_t \] (3)

where \( c^e_t \) denotes consumption of employed members and \( c^u_t \) is consumption of the unemployed. The working members of the households supply hours of labor at the competitive wage \( W_t \). The fraction of household members at work, is employed for \( n_t \) hours. The total numbers of hours worked is
thus $H_t = e_t n_t$. The household supplies capital services to firms at the competitive rental rate $R_t^K$. Capital services depend on the available stock of capital $K_t$ and on the degree of utilization $U_t$. Consumption goods can be transformed in investment goods at the price $q_t^{-1}$. The function $\nu(\cdot)$ has $\nu'(\cdot), \nu''(\cdot) > 0$. In particular, as discussed in section 5, we restrict $\nu(\cdot)$ such that, given $\sigma > 1$:

- individual labor supply has a constant Frish elasticity;
- utility is concave;
- consumption and leisure are normal goods.

This particular utility function is also consistent with a balanced growth path, – Basu and Kimball, 2000. More importantly, it implies that consumption and leisure are substitutes, as predicted by models of home production – Becker, 1965.

The function $\Phi(e_t)$ denotes a time-invariant cost of participation, which we keep distinct from the disutility incurred from hours worked – see for example Cho and Cooley, 1994. The cost function $\Phi(e_t)$ has the following properties

$\Phi(\bar{e}) > 0, \quad \Phi_e(\bar{e}) > 0, \quad \Phi_{ee}(\bar{e}) > 0$.

Investment adjustment costs depend on the function $\phi(\cdot)$ which satisfies the following properties

$\phi(1) = \phi'(1) = 0, \quad \phi''(1) \geq 0$.

Finally, the capital depreciation depends on the degree of capacity utilization according to the function

$\delta(\bar{U}) = \delta, \quad \delta'(\bar{U}) > 0, \quad \delta''(\bar{U}) > 0$.

**Labor supply.** The first order conditions with respect to consumption in the two groups gives

$$(c^*_t)^{-\sigma} \nu(n_t) = \lambda_t$$  \hspace{1cm} (4)
\[(c_t^u)^{-\sigma} \nu (0) = \lambda_t, \quad (5)\]

where \(\lambda_t\) is the Lagrange multiplier on the budget constraint, imply the following risk-sharing condition

\[
\frac{c_t^c}{c_t^u} = \left[ \frac{\nu (n_t)}{\nu (0)} \right]^{\frac{\sigma}{\sigma - 1}}, \quad (6)
\]

so that employed members enjoy more consumption in order to be compensated for the work effort. The first order condition with respect to the participation rate gives

\[
\frac{1}{1 - \sigma} \left[ (c_t^u)^{1-\sigma} \nu (0) - (c_t^c)^{1-\sigma} \nu (n_t) \right] = \lambda_t [W_t n_t - c_t^c + c_t^u] - \Phi_e (e_t) \quad (7)
\]

which, rearranging, becomes

\[
\frac{\sigma}{\sigma - 1} (c_t^c - c_t^u) = W_t n_t - \frac{\Phi_e (e_t)}{\lambda_t}. \quad (8)
\]

The first order condition with respect to hours gives

\[
\frac{(c_t^c)^{1-\sigma} \nu' (n_t)}{\sigma - 1} = \lambda_t W_t
\]

which after simplifying yields

\[
\frac{c_t^c \nu' (n_t)}{\sigma - 1} = \nu (n_t) W_t. \quad (9)
\]

**Supply of capital services.** The first order condition with respect to capital yields

\[
E_t \left\{ \beta \frac{\lambda_{t+1}}{\mu_t} (R_{t+1}^K U_{t+1}) + \frac{\mu_{t+1}}{\mu_t} [1 - \delta (U_t)] \right\} = 1 \quad (10)
\]

where \(\mu_t\) is the multiplier associated to the capital accumulation equation. Investment dynamics obeys to

\[
\frac{\lambda_t}{q_t} = \mu_t \left[ 1 - \phi \left( \frac{I_t}{I_{t-1}} \right) - \frac{I_t}{I_{t-1}} \phi' \left( \frac{I_t}{I_{t-1}} \right) \frac{I_t}{I_{t-1}} \phi' \left( \frac{I_t}{I_{t-1}} \right) \right] + \beta E_t \left[ \mu_{t+1} \left( \frac{I_{t+1}}{I_t} \right)^2 \phi' \left( \frac{I_{t+1}}{I_t} \right) \right]. \quad (11)
\]
and finally capacity utilization is determined by

\[ \lambda_t R^K_t = \mu_t \delta' (U_t) \, . \]  \hspace{1cm} (12)

**Firms.** Output is produced by perfectly competitive firms with the Cobb Douglas production function

\[ Y_t = (U_t K_t)^\alpha H_t^{1-\alpha} \, . \]  \hspace{1cm} (13)

Firms’ demand for labor and capital services is then

\[ R^K_t = \alpha \frac{Y_t}{U_t K_t} \]  \hspace{1cm} (14)

and

\[ W_t = (1 - \alpha) \frac{Y_t}{H_t} \]  \hspace{1cm} (15)

**Steady state.** The real interest rate is defined as

\[ \alpha \tilde{Y} \tilde{K} = \tilde{R}^k = \beta^{-1} - 1 + \delta, \]

where \( \tilde{X} \) denotes steady state values and we normalize \( \bar{U} = 1 \). From the capital accumulation equations we have

\[ \frac{\bar{I}}{\bar{K}} = \delta. \]

Next, define

\[ \psi = \frac{\bar{W} \bar{N}}{\bar{C}^*} = (1 - \alpha) \frac{\bar{Y}}{\bar{K}} \left( \bar{C} \bar{K} \right)^{-1} \]

\[ = \frac{(1 - \alpha) (\beta^{-1} - 1 + \delta)}{\beta^{-1} - 1 + (1 - \alpha)\delta} \]

using

\[ \frac{\bar{C}}{\bar{K}} = \frac{\bar{Y} - \bar{I}}{\bar{K}}. \]

From the first order condition for participation we get

\[ \frac{\sigma}{\sigma - 1} (\bar{c}^e - \bar{c}^n) = \bar{W} \bar{n} - \bar{\lambda}^{-1} \Phi_e (\bar{e}) \, . \]
We define $\omega = \bar{c}^u / \bar{c}^e$. Dividing for steady state consumption and re-arranging we get

$$\chi^{-1} \frac{\Phi_e (\bar{e}) \bar{e}}{\bar{C}} + \frac{\sigma}{\sigma - 1} (1 - \omega) s^e = \psi$$

where

$$s^e = \bar{c}^e \bar{e} / \bar{C} = \frac{\bar{e}}{\bar{e} + (1 - \bar{e}) \omega}.$$  

The parameter $\chi^{-1} \frac{\Phi_e (\bar{e}) \bar{e}}{\bar{C}}$ measures the marginal cost of participation in terms of consumption units (as a fraction of total consumption). We can express it as a fraction of wage earning

$$\chi^{-1} \frac{\Phi_e (\bar{e}) \bar{e}}{\bar{C}} = \frac{\zeta \bar{W} \bar{N}}{\bar{C}} = \zeta \psi.$$ 

This particular expression will be used in the calibration exercise in later sections. Hence, $\sigma$ is calculated as

$$\sigma = \frac{1 - \zeta}{1 - \zeta - (1 - \omega) \psi^{-1} s^e} \quad (16)$$

where the assumed calibration needs to satisfy $1 - \zeta - (1 - \omega) \psi^{-1} s^e > 0$.

Finally, the steady state amount of hours worked can be determined by $\nu(0)$,

$$\omega^{-1} = \left[ \frac{\nu (\bar{n})}{\nu (0)} \right] ^{\frac{1}{\bar{e}}}.$$ 

### 3.1 Non-separability, participation and comovement: an example.

In the sequel, we are going to consider a log-linear approximation of the model, around the nonstochastic steady state. In order to describe the intuition for the comovement result, let’s first consider a simple economy with no investment adjustment costs, no capacity utilization and no intensive margin. We further assume that there is a fixed cost of participating so that $\zeta = 0$. The log-linearized model is described in the appendix. The key intratemporal equations of the model are described by the following equations

$$(c^e_t - c^u_t) = \frac{(\sigma - 1)}{\sigma} W_t \bar{n} \quad (17)$$
where employed members of the household work a fixed number of hours \( \bar{n} \), and

\[
\frac{c^e_t}{c^u_t} = \left[ \frac{\nu(\bar{n})}{\nu(0)} \right]^{\frac{1}{\sigma}} \tag{18}
\]

which states that consumption of employed and not employed move proportionally. Aggregate consumption and the real wage are defined as in (3) and (15), while the aggregate resource constraint is

\[ C_t + I_t = Y_t. \]

Log-linearizing the intratemporal conditions and rearranging using steady-state definitions above yields the following "constant-consumption" aggregate labor supply

\[
\dot{C}_t = \dot{W}_t + \frac{(1 - \omega)}{1 + (\bar{e}^{-1} - 1)\omega} \dot{N}_t \tag{19}
\]

where in this simple version of the model \( N_t = \bar{n}e_t \). Notice that with \( \omega = 1 \) \( (\sigma = 1) \) the model implies a perfectly elastic labor supply, as in Rogerson’s (1988) lottery model, where employed and unemployed consume the same. With \( 0 < \omega < 1 \), employed members of the household consume more than the unemployed. This induces a positive relationship between aggregate consumption and aggregate hours supplied to the market, for a given real wage. Since capital is predetermined in the current period, (15) implies a negative relation between the real wage and the number of hours worked. In log-linear terms,

\[ \dot{W}_t = -\alpha \dot{N}_t. \]

Substituting in (19) and using the steady state restriction (16) we get a simple relation between total hours and aggregate consumption

\[
\dot{C}_t = \left[ \frac{(1 - \omega)}{1 + (\bar{e}^{-1} - 1)\omega} - \alpha \right] \dot{N}_t. \tag{20}
\]

On the one hand, increase in hours worked increases aggregate consumption because the fraction of employed increases. On the other hand, decreasing returns to the labor input implies that an increase in \( N_t \) decreases the real wage with a negative effect on aggregate consumption. As it is apparent from
(20) a sufficiently low value for $\omega$ guarantees positive comovement between consumption and total hours worked

\[ \frac{I}{Y} \hat{h} = \left[ (1 - \alpha) - \frac{C}{Y} \left( \frac{1 - \omega}{1 + (\bar{e}^{-1} - 1) \omega} - \alpha \right) \right] \hat{N}_t \]

where the coefficient is positive\(^1\) and increasing in $\omega$. The following Proposition summarizes the result.

**Proposition 1** Assume $\psi^{-1} s^e \in (0, 1]$. For a given $\bar{e} \in (0, 1)$ and $\alpha \in (0, 1)$, there exists an $\omega^*$ such that for $0 < \omega < \omega^*$ the economy displays positive comovement between aggregate hours, consumption and investment.

**Remark 2** The condition $\psi^{-1} s^e \in (0, 1]$ is easily met in a plausible calibration where $\psi \approx 0.8$ and $s^e \approx 0.7$. Moreover, the restriction applies only for $\omega \approx 0$, which is not empirically plausible.

**Remark 3** Notice that a perfectly elastic labor supply does not imply co-movement. The nonseparability of leisure and consumption is the key to the result.

Capacity utilization increases the ability of the model to generate comovement. To see this, consider a simpler version of the economy without intensive margin and adjustment costs to investment. Log-linearizing (12) and (14) and combining the two expressions we get

\[ \hat{U}_t = \frac{1 - \alpha}{\epsilon_\delta + 1 - \alpha} \hat{N}_t. \]

The wage then can be expressed as

\[ \hat{W}_t = \left( \frac{1 - \alpha}{\epsilon_\delta + 1 - \alpha} - 1 \right) \alpha \hat{N}_t, \]

\(^1\)Notice that for $\omega \to 0$,

\[ \frac{C}{Y} \left( \frac{1 - \omega}{1 + (\bar{e}^{-1} - 1) \omega} - \alpha \right) \to \frac{C}{Y} (1 - \alpha) < (1 - \alpha). \]
which, substituted in (19) yields
\[
\hat{C}_t = \left[ \frac{(1 - \omega)}{1 + (\hat{e}^{-1} - 1) \omega} + \left( \frac{1 - \alpha}{\epsilon_{\delta} + 1 - \alpha - 1} \right) \alpha \right] \hat{N}_t.
\]

Finally, the relation between investment and hours becomes
\[
\frac{I}{Y} \hat{I}_t = \left[ (1 - \alpha) - \frac{C}{Y} \left( \frac{1 - \omega}{1 + (\hat{e}^{-1} - 1) \omega} + \left( \frac{1 - \alpha}{\epsilon_{\delta} + 1 - \alpha - 1} \right) \alpha \right) \right] \hat{N}_t.
\]

In this case, provided \((1 - \alpha) > \frac{C}{Y}\) comovement between total hours and investment is guaranteed for every value of \(\epsilon_{\delta}\). We can then conclude that, 1) endogenous capacity utilization alone does not generate comovement in the economy with participation; 2) capacity utilization facilitates comovement, that is \(\frac{\partial \omega^*}{\epsilon_{\delta}} < 0\).

### 3.2 The full model

Here we set up the model with all the features.

**Extensive and intensive margins.** The labor supply part of the model features both intensive and extensive margins. We briefly discuss the log-linearized model that is derived in the appendix. The members of the household that are employed supply labor according to the following Frish labor supply

\[
\phi_N \hat{n}_t = \hat{W}_t + \sigma^{-1} \hat{\lambda}_t.
\]

or

\[
\phi_N \hat{n}_t = \hat{W}_t + \left[ 1 - \frac{1}{\psi (1 - \zeta)} \frac{(1 - \omega)}{1 + (\hat{e}^{-1} - 1) \omega} \right] \hat{\lambda}_t
\]

where \(\phi_N\) depends on the individual utility function and is restricted to be positive\(^2\). Combining (21) with the marginal utility of income

\[
\hat{\lambda}_t = -\sigma \hat{c}_t + \psi s_{t}^{-1} (\sigma - 1) \hat{n}_t
\]

we obtain a constant-consumption individual labor supply

\[
\left[ \phi_N - \frac{(\sigma - 1)}{\sigma} \psi s_{t}^{-1} \right] \hat{n}_t = \hat{W}_t - \hat{c}_t.
\]

\(^2\)As shown in the Appendix, concavity of the utility function requires \(\phi_N > 0\).
As derived in the Appendix, $\phi_N - \frac{(\sigma - 1)}{\sigma} \psi s_e^{-1} > 0$ implies that both consumption and leisure are normal goods (see also the discussion below). The smaller drop in consumption associated with an increase in hours worked is also evident from the consumption sharing rule

$$\hat{c}_t^e - \psi s_e^{-1} \frac{(\sigma - 1)}{\sigma} \hat{n}_t = \hat{c}_t^u. \tag{24}$$

However, introducing the intensive margin decreases the ability of the model to generate comovement. Individual hours worked and aggregate consumption display negative comovement because consumption and leisure are normal goods. Thus, the larger the role of the intensive margin in explaining total hours variation, the lower the comovement of aggregate consumption and aggregate hours.

Labor force participation is determined by

$$\frac{\sigma}{\sigma - 1} (\hat{c}_t^e - \omega \hat{c}_t^u) s^e = \psi \left( \hat{W}_t + \hat{n}_t \right) - \epsilon_e \zeta \psi \hat{e}_t + \zeta \psi \hat{\lambda}_t \tag{25}$$

where $\epsilon_e = \Phi''(\bar{e}) \bar{e} / \Phi'(\bar{e})$. Combining (24) and (25) we obtain the Frish elasticity of participation

$$\epsilon_e \hat{e}_t = \hat{W}_t + \left[ 1 - \frac{1}{\psi} \frac{(1 - \omega)}{1 + (\bar{e}^{-1} - 1) \omega} \right] \hat{\lambda}_t. \tag{26}$$

Finally, aggregate consumption in log-linear deviations,

$$\hat{C}_t = s_e \hat{c}_t^e + (1 - s_e) \hat{c}_t^u + (1 - \omega) s_e \hat{e}_t$$

depends on (weighted) individual consumption and the share of employed and unemployed. This ‘composition effect’ on aggregate consumption depends on $\omega$, the consumption share of the unemployed. Obviously, in the case of equal consumption of employed and unemployed ($\omega = 1$) there is no employment effect on aggregate consumption. The rest of the log-linearized model is described in the Appendix.

**Nonseparable preferences and the business cycle.** Nonseparable preferences in consumption and leisure have been proposed before in business cycle models. King and Rebelo (1999) and Hall (2008) show how nonseparable preferences increase comovement of consumption with output and hours,
when the main driving force of the business cycle are TFP shocks. Perhaps more related to this paper, nonseparable preferences have been proposed to explain business cycles in absence of productivity shocks. Farmer and Bennet (2000) show that nonseparable preference can help generating indeterminate equilibria and thus 'animal spirits' driven business cycles, but the chosen preference specification violates concavity – see Hintemaier (2003). Lienmann (2006) considers government spending shocks and shows that nonseparable preferences can generate comovement but, as shown in Bilbiie (2007), this implies that consumption is an inferior good. Bilbiie (2007) shows that for a general class of nonseparable preferences (which satisfies concavity and normality of both consumption and leisure) comovement between consumption and leisure cannot be obtained in a representative-agent model. The class of preferences considered in this paper satisfies both assumptions above, as showed in the Appendix. The comovement result arises because of both the assumption of nonseparability in the utility function and the introduction of the extensive margin in the labor market.

4 Calibration

The model is calibrated to US data. We set the discount factor $\beta = 0.99$, the capital share $\alpha = 0.3$ and the depreciation rate of capital to $\delta = 0.025$. These parameters imply a value for $\epsilon_{\delta} = \delta' (\bar{U}) / \delta' (\bar{U}) = 0.404$. We set $\epsilon_{\delta}$ by using the following, widely used functional form

$$\delta(U_t) = \frac{1}{\theta} U_t^{\theta}$$

which restricts $\theta = \delta^{-1} (\beta^{-1} - 1 + \delta)$ in steady state. This implies

$$\epsilon_{\delta} = \theta - 1.$$

These parameters are widely used in the literature. The labor supply dynamics of the model is affected by the steady state fraction of household members that participate in the labor market ($\bar{e}$), the marginal cost of participating

\( (\Phi_e(\bar{e})) \), the consumption of nonparticipating households as a fraction of participating households \( (\omega) \) and the inverse of the Frish elasticities of hours \( (\phi_N) \) and fraction of employed \( (\epsilon_e) \). We set \( \bar{e} = 0.68 \), roughly in line with the labor market participation rate in the US.

We choose a baseline specification for \( \omega = 0.8 \), implying that members of the households that do not participate to the labor market consume 20% less than employed members. The number is motivated by two main sources. First, we use CEX data on US households’ expenditures\(^4\) for 1980-2003. The dataset includes married couples with a minimum of 260 hours worked per year. We divide the sample in two groups: households that work less than 2600 hours in a year (which corresponds to the 25th percentile) and the rest. We find that households that work more than the threshold consume 19.2% more.\(^5\) Second, Aguiar and Hurst (2005) using the Continuing Survey of Food Intake of Individuals (CSFII) show that food consumption for unemployed falls about 19% after they enter into unemployment. These numbers are likely to understate the consumption gap between employed and unemployed. This because in our data calculation households working below the treshold still work for a nontrivial number of hours\(^6\) (in contrast to the model assumptions). Concerning the number in Aguiar and Hurst (2005), it is reasonable to assume that unemployed might cut more heavily on non-food consumption. However, the documented drop in consumption might capture the existence of borrowing constraints that are not included in our model.

In detail, our benchmark calibration implies a cross elasticity of consumption of the employed with respect to the wage of 0.45, which is obtained from combining (21) and (22),

\[
\tilde{\epsilon}_t^e = - \left[ 1 - \psi s_e^{-1} \left( \frac{\sigma - 1}{\sigma} \right) \right] \sigma^{-1} \lambda_t + \psi s_e^{-1} \left( \frac{\sigma - 1}{\sigma} \right) \hat{W}_t
\]

\(^4\)We thank Gianluca Violante for suggesting the data set and providing the data. The data used here are from Heathcoth et al (2008). A detailed description of the dataset can be found in Kruger and Perri (2006).

\(^5\)In detail, we regress consumption on the hours dummy, controlling for age, education, race, region, urban/rural and year. We find a strongly significant coefficient. For consumption, we use the variable consumption nondurable plus. This includes nondurable consumption and imputed services from nondurable goods such as housing. Details on how this variable is constructed can be found in Kruger and Perri (2007).

\(^6\)The first group of households (working more than 2600 hours) works on average twice as many hours than the second group. Still, the average number of hours worked in the second group is 2000, roughly corresponding the case in which a member of the couple has a full time job and the other is at home.
where $\phi_N = 1$. The number is above what is suggested in Hall (2008), which considers only unemployed agents. It comes from Browning and Crossley (2001), which studies declines in total consumption during periods of unemployment using Canadian data. Consumption of unemployed is assumed to be 15% below consumption of employed (which corresponds to a cross-elasticity of 0.33). The estimated\(^7\) cross elasticity in Hall (2008) model is equal to 0.53, corresponding to our baseline calibration of $\omega = 0.75$.

Next, we calibrate the value for the marginal disutility of working, defined as

$$\zeta \psi = \lambda^{-1} \Phi_e (\bar{e}) \bar{e} - \zeta \bar{W} \bar{N}.$$ \(\text{The parameter } \psi \text{ denoting total wage compensation as a fraction of total consumption is equal to 0.89, in line with empirical evidence. The remaining parameter, } \zeta, \text{ is equal to 0.55 which implies that the value of nonworking for any household member is about 45% of the value of working. to put this number in perspective, a value of } \zeta \text{ closer to 0.05 would correspond to the calibration of Hagedorn and Manovskii (2008). Our calibration is closer to Hall (2006), that is}

\begin{equation}
\left[ \frac{(\bar{e}^a)^{1-\sigma} \nu(0)}{1-\sigma} - \frac{(\bar{e}^n)^{1-\sigma} \nu(\bar{n})}{1-\sigma} \right] \lambda^{-1} \bar{e}^a + \bar{e}^c - \bar{e}^a = W \bar{n} - \Phi_e (\bar{e})
= W \bar{n} (1 - \zeta)
= 0.45 W \bar{n}.
\end{equation}

Given the chosen values for $\omega$ and $\zeta$, we set $\sigma = 1.56$, where

$$\sigma = \left[ 1 - \frac{1}{\psi} \frac{(1 - \zeta) (1 - \omega)}{(\bar{e}^c - 1) \omega} \right]^{-1}.$$ 

The value is in the mid-range between the values of 1 and 3 proposed in the literature. We assume that the ratio of the Frish elasticity of the supply of hours is one fourth the Frish elasticity of employment, $(\epsilon_c \zeta) / \phi_N = 1/4$, to roughly match the observed difference in their volatility\(^8\). Importantly, the

\(^7\)Here we refer to the mean of the posterior distribution. The prior is set to 0.3, consistent with $\omega = 0.85$. The posterior standard deviation is 0.09: our benchmark calibration is roughly one standard deviation below Hall (2008) estimated mean. For details of the model and estimation see Hall (2008).

\(^8\)Similar calibration is used in Dotsey and King (2006).
chosen value of $\phi_N$ satisfies the restriction

$$\phi_N - \frac{(\sigma - 1)}{\sigma} \psi s^{-1} > 0$$

across all our experiments, implying that consumption and leisure are normal goods. Finally, we set a low level of investment adjustment costs, with $\phi'' = 0.15$. Investment adjustment costs only play a role in the case of news shocks, as will be discussed in the sections below. The benchmark calibration is summarized in Table I.

| Table I. Benchmark Calibration. |
|---|---|---|---|---|---|---|---|---|
| $\omega$ | $\beta$ | $\phi_N$ | $\sigma$ | $\zeta \phi_e$ | $\varepsilon \delta$ | $\phi'' (1)$ | $\hat{\epsilon}$ | $\alpha$ | $\delta$ |
| 0.8 | 0.99 | 1 | 1.6 | 1/4 | 0.4 | 0.15 | 0.68 | 0.3 | 0.025 |

5 What drives business cycles?

In this section we describe the response of the economy to alternative ‘demand’ shocks that have been considered in the literature. We show how shocks to the marginal efficiency of investment can play an important role in economic fluctuations. However, we do not draw clear cut conclusions about the relative role of the individual shocks in the business cycle as this would require estimating a more complex model of the economy. We leave this for further research.

Neutral technology shocks. We briefly describe the effects of a TFP shock in our model. We consider an autoregressive shock with an autoregressive coefficient of 0.95. The impulse response to a standard deviation shock is showed in Figure 1. The model predicts a positive response of investment consumption, hours and employment. In accordance with King and Rebelo (1999) and Hall (2008) consumption displays a larger response for values of $\omega < 1$. The purpose of the this is to show that our calibrated model predicts plausible responses, compared to a benchmark RBC model.

Investment-specific shocks. We chose investment-specific shock as our first example for two reasons. First, as motivated by Greenwood et al (1988), investment specific shocks can be interpreted as shifts in the marginal efficiency of investment (or, alternatively, "news" about future returns
to investment), which Keynes (1936) considered a major source of business cycle fluctuations. In standard RBC models, investment-specific shocks coupled with endogenous capacity utilization, induce substitution of resources towards "new" investment goods, and toward higher usage of existing capital, inducing an increase in investment at the expense of consumption.

Second, Eusepi and Preston (2008) show that a standard RBC model augmented with adaptive learning produces expectation-driven-business cycles induced by "endogenous news shocks". The shift in expectations produces similar substitution effects as with investment-specific shocks. Third, investment-specific shocks have received a lot of interest as potentially the major force of business cycle variation, both in the empirical VAR literature - Fisher 2006 - and in structural DSGE models – Justiniano and Primiceri (2008). However, it has proven quite difficult to obtain positive comovement between consumption, hours and investment conditional on this type of shock, even in models that include a variety of nominal and real frictions –Justiniano et al. (2008).

We set $\rho_1$, the autocorrelation of the investment-specific shock, to be 0.95. The benchmark calibration delivers positive comovement for values of $\rho_1$ as low\footnote{To put it into perspective, the estimates range from 0.72 in Primiceri et. al (2008), 0.87 in Primiceri and Justiniano (2008). In calibrated models, Greenwood et al. (1988) use $\rho_1 = 0.84$ and Krussel et al. (1988) use $\rho_1 = 0.89$ in terms of quarterly frequency. In contrast, Rebelo and Jamovich (2007) assume unit root.} as 0.72. As mentioned above, the existence of adjustment costs to investment is not important to generate comovement in the model. The crucial ingredients are, 1) the existence of the extensive margin, 2) the nonseparability in the utility function and 3) endogenous capital utilization. The latter is needed to obtain comovement for empirically plausible model parameter values.

INSERT FIGURES 1-3

As shown in Figure 2, under the standard RBC calibration consumption drops on impact and stays below steady state for approximately eight quarters. The model with $\omega = 0.8$ produces instead the "right" comovement between investment, hours and consumption. Decreasing the value of $\omega$ to 0.75 generates a stronger response of aggregate consumption. As apparent from Figure 3, labor productivity increases (because of the higher utilization
of existing capital) but by less than consumption for $\omega < 1$ while the marginal utility of income and capacity utilization increase with the real interest rate. Figure 4 shows the different consumption response of employed and unemployed. Agents that do not supply labor experience lower consumption than in steady state while labor market participants slightly increase their consumption. (In absence of adjustment costs to investment their consumption would decrease slightly, consistent with them having normal preferences). The first determinant of aggregate consumption response is thus a composition effect. Working agents experience a minor reduction or a slight increase in their consumption so that aggregate consumption falls less. The second determinant is captured by the extensive margin.

INSERT FIGURE 4

As shown in Figure 4, employment responds more than individual hours. As the number of working agents increases, aggregate consumption increases as well. In a version of the model where all the adjustment occurs through the extensive margin, the response of consumption would be more pronounced. In terms of robustness, positive comovement depends on the magnitudes of adjustment costs and the persistence of the shock process. The higher adjustment costs and shock persistence, the larger the consumption response.

Next, we discuss few business cycle population statistics generated by the model assuming that investment specific shocks are the only driving force of aggregate fluctuations. We compare the three proposed calibrations discussed above. Investment-specific shocks in our model lead to a sizable amount of correlation between output and consumption, while maintaining high relative volatility in hours worked. Labor productivity maintains a positive correlation with output but is lower than consumption. Finally, consumption, output and investment growth rates display positive autocorrelation. However, consumption’s relative volatility (with respect to output) is significantly lower than in the data.
Table 2. I-shock

<table>
<thead>
<tr>
<th></th>
<th>$\omega = 1$</th>
<th>$\omega = 0.8 \ (0.75)$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\frac{\sigma_x}{\sigma_y}$</td>
<td>$c(x_t,Y_t)$</td>
</tr>
<tr>
<td>$C$</td>
<td>0.35</td>
<td>0.00</td>
</tr>
<tr>
<td>$I$</td>
<td>5.31</td>
<td>0.98</td>
</tr>
<tr>
<td>$N$</td>
<td>0.95</td>
<td>0.95</td>
</tr>
<tr>
<td>$Y$</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>$Y/N$</td>
<td>0.33</td>
<td>0.3</td>
</tr>
<tr>
<td>$W$</td>
<td>0.33</td>
<td>0.3</td>
</tr>
</tbody>
</table>

The table compares model-generated relative standard deviation with respect to output, correlation with output and autocorrelation of growth rates.

Table 3. Us data

<table>
<thead>
<tr>
<th></th>
<th>US Data</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\frac{\sigma_x}{\sigma_y}$</td>
</tr>
<tr>
<td>$C$</td>
<td>0.52</td>
</tr>
<tr>
<td>$I$</td>
<td>2.87</td>
</tr>
<tr>
<td>$N$</td>
<td>1.12</td>
</tr>
<tr>
<td>$Y$</td>
<td>1</td>
</tr>
<tr>
<td>$Y/N$</td>
<td>0.68</td>
</tr>
<tr>
<td>$W$</td>
<td>0.54</td>
</tr>
</tbody>
</table>

Notice two further statistics that have been discussed in business cycle literature. First, the correlation between hours spent producing for the consumption sector ($h_{c,t}$)

$$h_{c,t} = \frac{C_t}{Y_t} N_t$$

and output. In the benchmark calibration the model produces a correlation of $-0.16$, while in the model without nonseparability the correlation is $-0.95$ (the data show instead a positive correlation). The latter correlation turns positive if one assumes a slightly more elastic individual labor supply ($\phi_N = 0.7$, close to female labor supply elasticity) or in the alternative calibration with $\omega = 0.75$. Moreover, labor productivity is roughly 40% less volatile than total hours worked, not as volatile as in the data. Also, the correlation between hours and productivity is 0.02 in line with the low correlation observed in the data. Finally, the calibration implies that $\sigma_h/\sigma_e = 0.21$.
and \( \sigma_e/\sigma_N = 0.84 \) in line with the stylized facts about the relative volatility of hours and employment for the US data.

**Government spending shocks.** We consider a shock to the resource constraint, with autocorrelation coefficient of 0.95. The shock can be interpreted as a government spending shock, where resources are pulled out of the economy. As shown in Figure 5, in the benchmark calibration the model predicts a muted decrease in consumption and a drop in investment, while output and hours increase. This shows that the calibrated model cannot generate a joint positive response in both consumption and investment, as suggested by some VAR evidence – see for example Gali and Lopez-Salido, 2007, for a short survey of the literature. The main difference between government spending shocks and investment-specific shocks is that the high substitution effects are coupled with a negative wealth effect, as the resources available for investment and consumption shrink. Comovement can only be obtained in the variant of the model without intensive margin and with \( \omega = 0.85 \), as shown in Figure 6.

\[ \text {INSERT FIGURES 5-6} \]

The increase in employment leads to an increase in consumption while increasing the marginal product of capital and thus counteracting the crowding out effects on investment from the increase in consumption and government spending. Back to the benchmark model, the results are not inconsistent with fiscal policy having expansionary effects. The model combined with a small amount of nominal rigidities can possibly deliver an expansionary response, as in Gali and Lopez-Salido (2007).

**News shocks.** We define a “news shock” as new information about future productivity. Following the recent literature, we assume that the news shock is about future TFP. We model TFP shocks as in Christiano et al. (2008). Assume that TFP evolves according to the following process

\[ \hat{A}_t = \rho_a \hat{A}_{t-1} + \epsilon_{t-p} + \xi_t, \]

where \( \epsilon_t \) and \( \xi_t \) are i.i.d. disturbances. The shock \( \epsilon_t \) affects TFP \( p \)-periods later. As agents observe the shock \( \epsilon_t \), they can forecast future productivity. Notice that \( \epsilon_t \) does not affect current TFP. The model proposed in this paper
*without investment adjustment costs* cannot deliver the ‘right’ comovement after a news shock. In fact, consumption, hours and investment *comove together but in the opposite direction! For example, assume that agents expect productivity to be higher two quarters from now. The positive wealth effect induce an increase in individual consumption and leisure. However, labor market participation would drop as well, inducing a fall in aggregate consumption. This is because agents do not have incentives to work harder and invest in the current period in order to benefit from future productivity. The model with adjustment costs introduces substitution effects that can deliver the required comovement.

**INSERT FIGURES 7-9**

Figure (7)-(9) illustrate the response of the economy to the news of a positive productivity shock in the third quarter, where the horizon is chosen for comparison with the estimate of Schmitt-Grohe’ and Uribe (2008). The impulse response corresponds to the benchmark calibration. The three responses correspond to three different autocorrelation coefficients $\rho_a$: 0.75, 0.85 and 0.95. The intermediate value roughly corresponds to the calibration in Schmitt-Grohe’ and Uribe (2008) and Christiano et al (2008). They are chosen to illustrate the alternative responses of the economy to the news shock, which depends on the magnitude of the substitution effect. Two observations are due. First, in the model with $\omega = 1$, consumption would drop below its steady state value because of substitution effects. This can be seen in Figure 9: individual consumption drops after the initial increase, as it would in the model with $\omega = 1$. Second, in the benchmark calibration the intensive margin is quite responsive to the news shock.

**INSERT FIGURE 10**

Figure (10) shows the impulse response in the model where only the extensive margin is active. In this model a news shock produces the right comovement. Moreover, consumption keeps increasing until the big jump that occurs when the shock is realized.

Overall, the possibility of comovement depends on the strength of adjustment costs (which here is assumed very mild) and the persistence of the TFP
shock. The less persistent the productivity shock, the stronger the substitution effect, the higher the comovement. The role of news shocks (as defined in this section) in the business cycle is still controversial. Schmitt-Grohe’ and Uribe (2009) find that news shocks play a key role in business cycle fluctuations by estimating a structural DSGE model. Sims (2009) shows that news shock, as identified in a structural VAR, leads to a decrease in hours and investment, and a small increase in consumption. The decrease in consumption is smaller than predicted by the benchmark RBC model and not inconsistent with our modified economy.

6 Discussion

[TO BE ADDED]

7 Conclusion

[TO BE ADDED]
8 Appendix

8.1 Nonseparable utility and the normality of consumption and leisure

Consider the individual working households with preferences with utility

\[ U(c_t, l_t) = \left(\frac{c_t}{1-\sigma}\right)^{1-\sigma} \left(\frac{1-l_t}{1-\sigma}\right)^{\sigma} \]

(27)

where \( n_t = 1 - l_t \) and \( l_t \) denotes time not spent in market activities and where \( \nu'(n), \nu''(n) > 0 \). Her individual budget constraint can be expressed as

\[ c_t + l_t W_t = M_t \]

(28)

where \( M_t \) denotes nonlabor income. Next, define

\[ \epsilon_{\nu} = \frac{\nu''(\bar{N})}{\nu'(\bar{N})} \bar{N} \]

The following Lemma states the first restriction on utility that guarantees concavity.

**Lemma 4** Assume \( \epsilon_{\nu} \) satisfies the restriction

\[ \epsilon_{\nu} > \frac{(\sigma - 1)^2}{\sigma} \psi s e^{-1}, \]

then the utility function (27) is concave.

**Proof.** Let us consider (27) in terms of consumption and leisure. Then we have

\[ U_t = -\frac{c_t^{1-\sigma}}{1-\sigma} \nu'(1 - l_t) > 0 \]
where $U_x$ denoted the marginal utility with respect to the argument $x$, and where, as above $\nu'(\cdot)$ denotes the derivative of $\nu(\cdot)$ with respect to hours worked. Similarly we get

$$U_{ll} = C^{1-\sigma} \nu''(1-l) < 0.$$ 

It is straightforward to show that $U_c > 0$ and $U_{cc} < 0$. Further, concavity requires

$$U_{cc} \cdot U_{ll} - (U_{cl})^2 \geq 0.$$ 

Substituting for the actual expressions we get

$$\frac{\sigma}{\sigma - 1} \nu(n) \nu''(n) c^{-2\sigma} - c^{-2\sigma} \nu'(n)^2$$

which simplifying yields

$$c^{-2\sigma} \nu'(n) \frac{n}{\nu(n)} \left[ \frac{\sigma}{\sigma - 1} \epsilon_\nu - \frac{\nu'(n) n}{\nu(n)} \right].$$

Evaluating this condition at the model’s steady state where

$$\frac{\nu'(\bar{n}) \bar{n}}{\nu(\bar{n})} = \frac{\bar{W} \bar{n}}{\bar{c}^e} (\sigma - 1) = \psi s_e^{-1} (\sigma - 1) \tag{29}$$

so that concavity requires

$$\left[ \epsilon_\nu - \psi s_e^{-1} \frac{(\sigma - 1)^2}{\sigma} \right] \geq 0.$$

The next Lemma states the restrictions required for both consumption and leisure to be normal goods.

**Lemma 5** Consumption and leisure are normal goods iff

$$\epsilon_\nu > (\sigma - 1) \psi s_e^{-1}.$$ 

Violation of the above condition implies that consumption is an inferior good.
Proof. Consider the first order conditions of the static utility maximization in (27) and (28). Total differentiation of the individual first order conditions and budget constraint gives

\[
(WU_{cc} - U_{cl}) \frac{\partial c}{\partial M} + (WU_{Cl} - U_{ll}) \frac{\partial l}{\partial M} = 0
\]

\[
\frac{\partial c}{\partial M} + W \frac{\partial l}{\partial M} = 1
\]

where \(W\) is kept constant and \(M\) denotes non-wage income. We have,

\[
\frac{\partial c}{\partial M} = \left[1 - W \frac{U_{cl} - WU_{cc}}{U_{ll} - WU_{cl}}\right]^{-1}
\]

\[
= \left[1 - \frac{U_{l} \frac{U_{cl}}{U_{l}} - \frac{U_{cc}}{U_{l}}}{U_{c} \frac{U_{l}}{U_{c}} - \frac{U_{ll}}{U_{c}}}\right]^{-1}.
\]

Substituting for the chosen utility and using the steady state restriction () we get

\[
\frac{\partial c}{\partial M} = \left[1 + \frac{\psi}{\epsilon_{\nu} - (\sigma - 1) \psi s_{e}^{-1}}\right]^{-1}
\]

which states that consumption is an inferior good if and only if

\[
\epsilon_{\nu} < (\sigma - 1) \psi s_{e}^{-1}.
\]

Next, the condition to have both consumption an leisure normal good is

\[
\frac{U_{cl}/U_{l} - U_{cc}/U_{c}}{U_{ll}/U_{l} - U_{cl}/U_{c}} < 0.
\]

Substituting for our chosen functional forms we get

\[
\frac{1 - l}{c} - \epsilon_{\nu} + (\sigma - 1) \psi s_{e}^{-1} < 0
\]

if and only if

\[
\epsilon_{\nu} > (\sigma - 1) \psi s_{e}^{-1}.
\]
8.2 The log-linearized model I: individual labor supply and normality

Log-linearizing (9) gives

$$-(\sigma - 1) \ddot{c}_t^e + \epsilon_{v} \dot{n}_t = \dot{\lambda}_t + \dot{W}_t.$$  \hspace{0.5cm} (30)

Combining with

$$\dot{\lambda}_t = -\sigma \ddot{c}_t^e + \psi \dot{s}_e^{-1} (\sigma - 1) \dot{n}_t,$$  \hspace{0.5cm} (31)

obtained by log-linearization of (4) we get the Frish individual labor supply

$$\phi_N \dot{n}_t = \dot{W}_t + \sigma^{-1} \dot{\lambda}_t.$$  \hspace{0.5cm} (32)

where the inverse of the Frish elasticity is defined as

$$\dot{\phi}_N = \epsilon_{v} - \frac{(\sigma - 1)^2}{\sigma} \psi \dot{s}_e^{-1}.$$

As shown in Lemma 1, concavity of the utility function requires $\phi_N > 0$. We can also express the condition for normality of consumption and leisure in terms of $\phi_N$. The implied restrictions on the labor supply are summarized in the following proposition.

**Proposition 6** Consider $\phi_N = \frac{(\sigma - 1)\psi s_e^{-1}}{\sigma}$. For $\phi_N \in (0, \bar{\phi}_N)$

1) the utility function is concave;

2) consumption and leisure are normal goods.

This restriction implies that the constant-consumption labor supply (23) is upward sloping, as also discussed in Bilbiie (2007).

8.3 The log-linearized model II

Substituting in (32) for the steady state value of $\sigma$ and for the definition of $s_e$ we obtain

$$\phi_N \dot{n}_t = \dot{W}_t + \left[ 1 - \frac{1}{\psi} \frac{(1 - \zeta)(1 - \omega)}{1 + (\bar{e}^{-1} - 1) \omega} \right] \dot{\lambda}_t.$$  \hspace{0.5cm} (33)

Log-linearizing the consumption-sharing condition (6) yields

$$\ddot{c}_t^e - \psi s_e^{-1} \frac{\sigma - 1}{\sigma} \dot{n}_t = \ddot{c}_t^u,$$  \hspace{0.5cm} (34)
where

\[-\sigma \hat{c}_t^u = \hat{\lambda}_t.\] (35)

Employment is determined by (7). Log-linearizing we get

\[
\frac{\sigma}{\sigma - 1} (\hat{c}_t^e - \omega \hat{c}_t^u) s^e = \psi \left( \hat{W}_t + \hat{\pi}_t \right) - \epsilon_e \lambda^{-1} \frac{\Phi_e \hat{e}_t}{C} + \lambda^{-1} \frac{\Phi_e \hat{e}_t}{C} \hat{\lambda}_t
\]

where

\[\epsilon_e = \frac{\Phi_e \hat{e}_t}{\Phi_e}.
\]

Using the assumption that the marginal cost of participating in terms of the consumption good is a fraction of labor earnings,

\[\lambda^{-1} \frac{\Phi_e \hat{e}_t}{C} = \zeta \psi,
\]

we get (25). Furthermore, Combining (34) and (25) we obtain the frish elasticity of participation

\[\epsilon_e \zeta \hat{e}_t = \hat{W}_t + \left[ \frac{(1 - \omega) s^e}{\psi (\sigma - 1)} + \zeta \right] \hat{\lambda}_t.\] (36)

By substituting for the values of \(\sigma\) and \(s^e\) that are consistent with the steady state we get (26).

Consider consumption and capital dynamics. Log-linearization of equations (10), (11) and (12) yields

\[\epsilon_\delta \hat{U}_t = \hat{R}_t^K + \hat{\lambda}_t - \hat{\mu}_t,\] (37)

where

\[\epsilon_\delta = \delta'' \bar{U}/\delta',\]

\[\hat{\mu}_t = E_t \left[ (1 - \beta (1 - \delta)) \left( \hat{R}_{t+1}^K + \hat{\lambda}_{t+1} \right) + \beta (1 - \delta) \hat{\mu}_{t+1} \right],\] (38)

and

\[\hat{\lambda}_t - \hat{\mu}_t - \hat{q}_t = -\phi'' \left( \hat{I}_t - \hat{I}_{t-1} \right) + \beta E_t \phi'' \left( \hat{I}_{t+1} - \hat{I}_t \right).\] (39)

The capital accumulation equation (2) and the resource constraint (1) are

\[\hat{K}_{t+1} = (1 - \delta) \hat{K}_t + \delta \hat{I}_t - (\beta^{-1} - 1 + \delta) \hat{U}_t\]

and

\[\frac{\bar{I}}{Y} \left( \hat{I}_t - \hat{q}_t \right) + \frac{\bar{C}}{Y} \hat{C}_t + \hat{G}_t = \hat{Y}_t.
\]
Finally, the log-linearized first order condition of the firm become

\[ \dot{W}_t = \dot{Y}_t - \dot{N}_t, \]

where

\[ \dot{Y}_t = \dot{A}_t + \alpha \left( \dot{K}_t + \dot{U}_t \right) + (1 - \alpha) \dot{N}_t, \]

\[ \dot{N}_t = \dot{\varepsilon}_t + \dot{n}_t, \]

and

\[ \dot{R}_t^k = \dot{Y}_t - \dot{K}_t - \dot{U}_t. \]
Figure 1: Impulse response to a TFP shock. Dotted line: benchmark. Plus-shaped line: $\omega = 0.75$. Diamond-shaped line: $\omega = 1$. 
Figure 2: **Impulse response to an investment-specific shock.** Dotted line: benchmark calibration. Plus-shaped line: $\omega = 0.75$. Diamond-shaped line: standard RBC ($\omega = 1$).
Figure 3: **Impulse response to an investment-specific shock.** Dotted line: benchmark calibration. Plus-shaped line: $\omega = 0.75$. Diamond-shaped line: standard RBC ($\omega = 1$).
Figure 4: **Impulse response to an investment-specific shock.** Dotted line: benchmark calibration. Plus-shaped line: $\omega = 0.75$. Diamond-shaped line: standard RBC ($\omega = 1$).
Figure 5: Impulse response to a government spending shock. Dotted line: benchmark calibration. Plus-shaped line: $\omega = 0.75$. Diamond-shaped line: standard RBC ($\omega = 1$).
Figure 6: Impulse response to a government spending shock. Extensive margin only. Dotted line: benchmark. Plus-shaped line: $\omega = 0.75$. Diamond-shaped line: $\omega = 1$. 
Figure 7: **Impulse response to a news shock.** Higher productivity materializes on the third quarter \((p = 2)\). Dotted line: \(\rho_a = 0.85\). Plus-shaped line: \(\rho_a = 0.75\). Diamond-shaped line: \(\rho_a = 0.95\).
Figure 8: Impulse response to a news shock. Higher productivity materializes on the third quarter ($p = 2$). Dotted line: $\rho_a = 0.85$. Plus-shaped line: $\rho_a = 0.75$. Diamond-shaped line: $\rho_a = 0.95$. 
Figure 9: **Impulse response to a news shock.** Higher productivity materializes on the third quarter \( (p = 2) \). Dotted line: \( \rho_a = 0.85 \). Plus-shaped line: \( \rho_a = 0.75 \). Diamond-shaped line: \( \rho_a = 0.95 \).
Figure 10: Impulse response to a news shock with extensive margin only. Higher productivity materializes on the third quarter ($p = 2$). Calibration: $\rho_a = 0.85$. 