Technology, Employment, and the Business Cycle: Do Technology Shocks Explain Aggregate Fluctuations? Comment

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Abstract

The neoclassical effects of permanent technology shocks on employment is re-investigated. Contrary to Jordi Gali's (1999) assertion published in this *Review*, I show that standard neoclassical theory is fully capable of explaining the stylized fact that positive permanent technology shocks reduce employment and that positive transitory nontechnology shocks increase labor productivity.

Technology, Employment, and the Business Cycle: Do Technology Shocks Explain Aggregate Fluctuations? Comment

In an earlier article in this *review*, Jordi Gali (1999) documents a striking empirical regularity in both the US economy and other industrialized economies: a permanent increase in total factor productivity reduces employment; and a temporary increase in aggregate demand increases both employment and labor productivity. In other words, under permanent technology shocks employment is negatively correlated with labor productivity, and under transitory shocks to demand employment is positively correlated with labor productivity. Jordi Gali asserts that these facts are inconsistent with conventional neoclassical equilibrium business cycle theory. He argues that new Keynesian theory with sticky prices and demand constraints is better able to explain these empirical facts. I find Gali's assertion warrants discussions. I show in this Comment that the first empirical regularity listed above – positive technology shocks reduce employment – is perfectly consistent with conventional neoclassical theory; and that the second empirical regularity – positive demand shocks lead to increases in labor productivity – can also be easily explained by real business cycle theory if mild increasing returns to scale is allowed for in an otherwise standard RBC model.

The reminder of this Comment is organized as follows. Section 1 presents a neoclassical explanation for the observed negative effects of permanent technology changes on employment. Section 2 presents a fully calibrated real business cycle model to show quantitatively the negative effects of technology shocks on employment and the positive effects of demand shocks on labor productivity. Section 3 deduces the relative contributions of technology shocks to business cycles implied by the model. Section 4 concludes.

1. The Neoclassical Effect of Permanent Technology Shock on Employment

According to Gali, the fact that a permanent increase in technology reduces employment cannot be explained by neoclassical models in which prices adjust instantaneously to clear markets. He shows that the empirical fact is nevertheless consistent with a version of the Keynesian theory in which the aggregate supply is constrained by aggregate demand. Since demand is not affected by supply shocks when prices are sticky, thus to produce the same amount of output with higher total factor productivity, labor demand has to decrease. In what follows, I show that neoclassical explanations do exist. It is a standard story of income and substitution effects. A permanent increase in technology can reduce employment if the income effect dominates the substitution effect.

For simplicity, assume that the utility function is separable in consumption c and leisure $1-n$:

$$u(c,n) = u(c) - \varphi(n), \tag{1}$$

where n is the fraction of time endowment devoted to work and $\varphi(\cdot)$ is convex in n. In a standard RBC model, the equilibrium condition in the labor market is given by

$$\varphi'(n) = u'(c)w, \tag{2}$$

where w is the real wage (the marginal product of labor). The left hand side of equation (2) is the marginal cost (disutility) of labor supply, and the right hand side is the utility value of the real wage. Notice that φ' is increasing in n and that the marginal utility of consumption u' is the shadow price of real income. Consider a permanent technology shock that increases the productivity of labor. The real wage goes up and the cost of leisure increases. Under the substitution effect, labor supply increases. On the other hand, there also exists an income effect that renders consumption to increase and the marginal utility of consumption (the shadow price) u' to decrease. Whether labor supply increases or not depends crucially on whether the substitution effect dominates the income effect. In particular, if the utility value of the real wage (the right hand side of equation 2) increases because the percentage reduction in the marginal utility (the shadow price) is less than the percentage increase in real wage (labor productivity), then the substitution effect dominates, hence labor supply increases. Consequently labor productivity and employment are positively correlated. If the utility value of real wage decreases because the percentage reduction in the marginal utility (the shadow price) is more than the percentage increase in the real wage, then the income effect dominates, hence leisure increases and labor supply decreases. Consequently labor productivity and employment are negatively correlated.

The question is under what conditions the income effect dominates. In order for the income effect to dominate the substitution effect, the percentage decrease in the shadow price (marginal utility) needs to dominate the percentage increase in the real wage (labor productivity) when a permanent technology shock takes place. I give two examples in which this can happen. The first example is when there exists a habit level (or subsistence level) of consumption, say Δ, so that the utility of consumption at level c is given by $u(c - \Delta)$. When $\Delta > 0$, the percentage decreases in the marginal utility due to an equal increase in consumption are magnified by the multiplier

$$\frac{c}{c - \Delta} > 1. \tag{3}$$

The multiplier can be very large if the habit consumption Δ is sufficiently close to the steady state consumption c. A large enough multiplier renders a large decline in the shadow price (hence a net decrease on the right hand side of equation 2) after a positive productivity shock.

The second example is when there exists government spending so that the resource constraint is given by

$$c_t + g + i_t = y_t, \tag{4}$$

where g is a fixed amount of government spending and i is private investment. By the permanent income theory, most of the impact of a permanent technology shock is absorbed into consumption. So we can log-linearize and approximate the percentage changes of the resource constraint as

$$\frac{c}{c + g}\hat{c}_t = \hat{y}_t. \tag{5}$$

It implies that the income effect on consumption is magnified by the multiplier $\frac{c+g}{c} > 1$, indicating that one percent increase in real income leads to a more than one percentage increase in consumption when government spending is positive. Such a multiplier effect on consumption can also lead to a large decline in the shadow price (marginal utility) in equation (2), rendering the utility value of the real wage decrease. Hence labor supply (the left hand side of equation 2) must go down in response to the permanent increase in technology.

2. **The Full Model**

This is the one-sector RBC model with variable capacity utilization based on Greenwood *et al.* (1989) and Burnside and Eichenbaum (1996). To generate procyclical productivity under demand shocks, I allow for mild externalities in the production technology.[1] A representative agent in the model chooses sequences of consumption, hours, capacity utilization, and capital accumulation to solve

$$\max \ E_0 \sum_{t=0}^{\infty} \beta^t \left(\log(c_t - \Delta_t) - a \frac{n_t^{1+\gamma}}{1+\gamma} \right) \tag{6}$$

subject to

$$c_t + i_t + g_t = A_t \Phi_t \left(e_t k_t \right)^{\alpha} n_t^{(1-\alpha)}, \tag{7}$$

$$k_{t+1} = i_t + (1 - \delta_t) k_t; \tag{8}$$

where Δ_t represents a stochastic subsistence level of consumption with mean Δ, which generates the urge to consume out of the steady state and is therefore interpreted as shocks to consumption demand (Baxter and King, 1992); A_t represents a random shock to technology with mean equal to unit; g_t is government spending – an exogenous stochastic process representing a pure resource drain on the economy (Christiano and Eichenbaum, 1992); $e \in [0, 1]$ in the production function denotes capital utilization rate, and Φ is a measure of production externalities and is defined as a function of average aggregate output which individuals take as parametric:

$$\Phi = \left[(ek)^{\alpha} n^{1-\alpha} \right]^{\eta}, \quad \eta \geq 0. \tag{9}$$

When the externality parameter η is zero, the model is reduced to a standard RBC model studied by Greenwood *et al* (1988). To have an interior solution for e in the steady state, I follow Greenwood *et al.* by assuming that the capital stock depreciates faster when being used more intensively:

$$\delta_t = \lambda e_t^{\theta}, \quad \theta > 1; \tag{10}$$

which imposes a convex cost structure on capital utilization.

2.1. Calibration

I calibrate the structural parameters of the model as follows. I set the capital share $\alpha = 0.3$, the time discount factor $\beta = 0.99$, the elasticity parameter

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[1] See Wen (1998) and Benhabib and Wen (2000).

of labor supply $\gamma = 0.15$, and choose the capacity elasticity parameter $\theta = 1.4$ so that the rate of capital depreciation in the steady state is 10 percent a year. As a benchmark value, I set the externality parameter $\eta = 0.12$, which is small enough so that the model's steady state is locally determinate.[2] The value is empirically plausible even judged by most recent empirical estimates on returns to scale (e.g., Basu and Fernald, 1997; Burnside *et al.,* 1995, and Conley and Dupor, 2000). The model's equilibrium decision rules are solved by log linearization around their steady state values. Technology is modeled as a random walk in log:

$$\log A_t = \log A_{t-1} + \varepsilon_{at}. \tag{11}$$

The two aggregate demand shocks (Δ_t, g_t) are both modeled as $AR(1)$ stationary processes:

$$\begin{bmatrix} \log(\Delta_t) \\ \log(g_t) \end{bmatrix} = \begin{bmatrix} (1-\rho_\Delta)\log(\Delta) \\ (1-\rho_g)\log(g) \end{bmatrix} + \begin{bmatrix} \rho_\Delta \log(\Delta_{t-1}) \\ \rho_g \log(g_{t-1}) \end{bmatrix} + \begin{bmatrix} \varepsilon_{\Delta t} \\ \varepsilon_{gt} \end{bmatrix}, \tag{12}$$

with $\rho_\Delta = \rho_g = 0.9$ and the covariance matrix:

$$var \begin{pmatrix} \varepsilon_{\Delta t} \\ \varepsilon_{gt} \\ \varepsilon_{at} \end{pmatrix} = \begin{bmatrix} \sigma_\Delta^2 & 0 & 0 \\ 0 & \sigma_g^2 & 0 \\ 0 & 0 & \sigma_a^2 \end{bmatrix}. \tag{13}$$

2.2. Dynamics

I first examine the impulse responses of hours to technology shocks in the model. The steady state values of the two ratios, the government expenditure to GDP ratio (g/y) and the subsistence consumption to consumption ratio (Δ/c), are the most crucial for determining the sign of labor's responses to a permanent technology shock. Figure 1 shows the responses of hours to a positive permanent technology shock when the two ratios take different values. The line with solid circles represents the case when both ratios are zero. It is seen there that permanent technology shock generates positive responses from labor (the substitution effect dominates). The line with empty circles represents the case where the subsistence consumption to consumption ratio

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[2] For analytical conditions of indeterminacy in this model, see Wen (1998).

is positive and sufficiently large ($\Delta/c = 0.6$). It shows that hours decrease permanently in response to the technology shock (the income effect dominates). Similarly, if the government spending to output ratio is large enough ($g/y = 0.4$), hours also respond to the shock negatively, as the line with solid triangles shows. The line with empty triangles shows that if both ratios are positive, then smaller values for these ratios are sufficient to generate negative effects of technology shocks on hours.

It is important to stress that the negative effect of permanent technology shocks on employment does not hinge on the assumption of variable capacity utilization or externalities. A large enough value for Δ/c or g/y is sufficient for generating a large enough income effect on labor supply. In the following simulations, I set $\Delta/c = 0.4$ and $g/y = 0.2$ as benchmark values.[3]

Another empirical regularity identified by Gali (1999) is that transitory shocks generate positive correlations between labor productivity and employment. Although Gali interprets transitory shocks as demand shocks, the possibility cannot be ruled out that they may also include transitory supply shocks such as transitory shocks to oil prices. Gali's sticky price model, however, predicts that transitory technology shocks also generate the opposite movement in hours. This would be inconsistent with the date if the identified transitory shocks from data were largely composed of transitory supply shocks. My model predicts that the responses of hours to transitory technology shocks are always positive, as shown in figure 2. The intuition is that transitory technology shocks induce only small income effect, as it induces only small increases in consumption and therefore only small decreases in the shadow price (marginal utility).[4]

A large portion of the transitory shocks in the US economy is arguably demand shocks. It is therefore crucial that my RBC model can generate positive comovement between labor productivity and employment under demand shocks. Figure 3 shows the responses of hours and labor productivity to de-

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[3] These values are conservative and they roughly match the post-war US data. The share of total government expenditure to GDP is about 20-25 percent in the US economy. There is no direct empirical evidence on the size of Δ/c, but literatures on habit formation normally find that the habit level of consumption is large relative to current consumption (at least 40 percent). For example, Ferson and Constantinides (1991) apply GMM procedure to estimate a time-nonseparable utility function and find that ratio to be around $0.6 - 0.9$ depending on the instrumental variables used.

[4] Note that the approximation in equation 5 is no longer valid under transitory technology shocks.

mand shocks. The top window shows the case of a positive consumption demand shock (Δ_t) and the bottom window shows the case of a positive government spending shock (g_t).[5] Both types of demand shocks generate positive correlations between labor productivity and employment.

Table 1 reports the conditional correlations between productivity growth and employment growth implied by the model under the benchmark parameter values. Also reported in table 1 are the estimated conditional moments of the US data by Gali (1999). Gali's point estimate (standard errors in parenthesis) on the conditional productivity-employment correlation is -0.84 for technology shocks and is 0.64 for demand shocks. The RBC model predicts that correlation to be -1.0 for technology shock and 0.99 for either consumption demand shock (Δ_t) or government shock (g_t). The predictions of the model under benchmark parameter values are thus qualitatively consistent with the data.

Table 1. Conditional Correlations $\rho(\Delta y - \Delta n, \Delta n)$

	US Economy	Model
Technology	$-0.84(0.12)$	-1.0
Nontechnology	0.64(0.13)	0.99

3. The Contribution of Technology Shocks to Business Cycles

The fact that the unconditional correlation between labor productivity and employment is close to zero is one of the most celebrated empirical regularities of the business cycle, first studied by Dunlop and Tarshis in the 1930s.[6] Aiyagari (1994) uses this piece of information to assess the relative contribution of technology shocks to the business cycle. Aiyagari's assessment, however, is based implicitly on the assumption that positive technology shocks induce positive movement in hours. He also made many simplifying assumptions (e.g., no capital and no capacity utilization). I reassess the statistic using a fully specified RBC model.

Two pieces of information are crucial for my computations: the conditional productivity-employment correlations with respect to technology shocks and nontechnology shocks. In my model, the crucial parameter that determines

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[5] The parameter values are $\rho_\Delta = \rho_g = 0.9$, $\sigma_\Delta = \sigma_g = 1$. For viewing purpose, the magnitudes of productivity's responses are enlarged by 10 times.

[6] See Eichenbaum and Christiano (1992).

the degree of negative correlation conditional on technology shocks (after controlling for the government spending to output ratio) is Δ/c, and the crucial parameter that controls the degree of positive correlation conditional on demand shocks is the externality parameter η. I estimate the two parameters by method of moments, namely, by simulating the model 500 times with sample length of 140, so that the means of conditional correlations of productivity and hours match Gali's point estimates. My computation shows that to match Gali's point estimates on the two conditional moments, I need $\Delta/c = 0.345$ and $\eta = 0.0973$. Under these parameter values, the conditional correlations implied by the model based on 500 simulations are reported in table 2, which shows that the model is capable of matching the data exactly with tight standard errors.[7]

Table 2. Conditional Correlations $\rho(\Delta y - \Delta n, \Delta n)$

	US Economy	Model	
Technology	-0.84	$-0.84(0.001)$	
Nontechnology	0.64	$0.64(0.01)\vert_{\Delta_t}$	$0.64(0.01)\vert_{g_t}$

I then allow both technology shocks and non-technology shocks (either Δ_t or g_t) in my model so that the unconditional productivity-employment correlation (under both technology and nontechnology shocks) is zero. Under this moment restriction, I am able to obtain the conditional variance of output with respect to technology shocks. The results from 500 simulations are reported in table 3 (standard errors in parenthesis). Numbers in the second column are productivity-employment correlations with respect to different shocks. Numbers in the third column are the implied variance of output growth under different shocks. Both the unconditional and the conditional correlations are calibrated to match Gali's point estimates in mean (second column). Comparison of unconditional and conditional variances shows that technology shock contributes only about 3% to the total variance of output growth regardless the source of non-technology shocks. This is consistent with Gali's (1999) empirical findings in the US economy.

It must be pointed out, however, that the result is very sensitive to the accuracy of the point estimate on the unconditional productivity-employment

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[7] The conditional correlations under Δ_t shock and g_t shock respectively turn out nearly identical, implying that it does not matter in the model which shock is active.

correlation. For example, if that correlation is not exactly zero but slightly less than zero, say -0.1, then the model-implied contribution from technology shocks to the variance of output growth increases to 43%. This is so because the model requires a substantial increase in the variance of technology shocks relative to the variance of nontechnology shocks in order to generate a negative unconditional productivity-employment correlation.

Table 3. Contribution to Business Cycle

	$\rho(\Delta y - \Delta n, \Delta n)$	$\sigma^2_{\Delta y}$
$A_t + \Delta_t$	$-0.003(0.007)$	$0.0413(2.6 \times 10^{-5})$
$A_t + g_t$	$-0.004(0.007)$	$0.0401(2.3 \times 10^{-5})$
A_t	$-0.84(0.001)$	$0.0016(3.5 \times 10^{-8})$
Δ_t	$0.64(0.006)$	$0.0397(2.3 \times 10^{-5})$
g_t	$0.64(0.005)$	$0.0386(2.1 \times 10^{-5})$

4. **Conclusions**

The neoclassical implications of permanent technology changes for employment is re-investigated. Contrary to Gali's (1999) assertion, I show that standard neoclassical theory is fully capable of explaining the observed negative effects of positive technology shocks on employment. With mild externalities, the neoclassical model is also capable of explaining the positive effects of nontechnology shocks on labor productivity. The possibility of a decline in employment in response to a permanent technology increase in the neoclassical model does not hinge on the assumptions of variable capacity utilization and externalities. It hinges only on the assumption of positive subsistence consumption in the utility function or positive government expenditure in the resource constraint. These assumptions give rise to a powerful income effect over the substitution effect on leisure choice, rendering labor supply to decline in response to a permanent increase in technology. Under these assumptions, however, the neoclassical model generates *permanent* changes in employment when technology shocks are permanent. This implication deserves further scrutiny and empirical test. The US data seem suggest that employment changes are temporary, although permanent effects are observed in other industrialized economies (see figure 5 in Gali, 1999).

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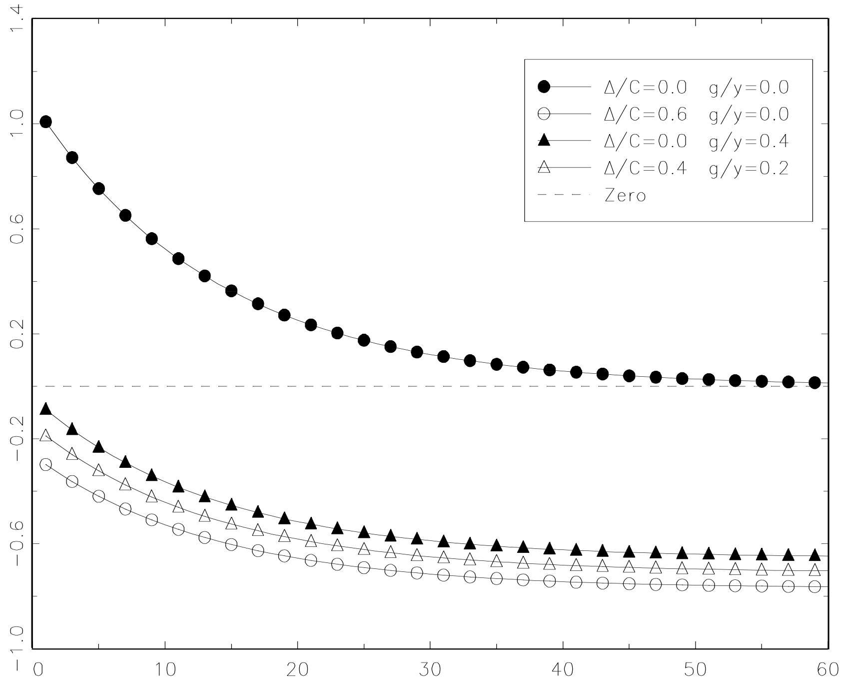

Figure 1. Impulse Responses of Hours to a Permanent Technology Inrease.

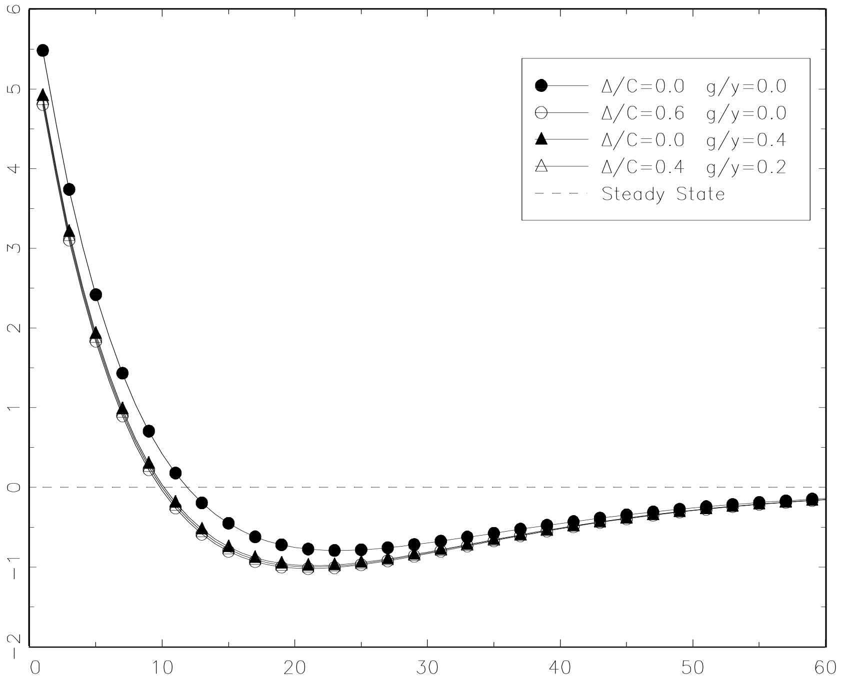

Figure 2. Impulse Responses of Hours to a Temporary Technology Increase.

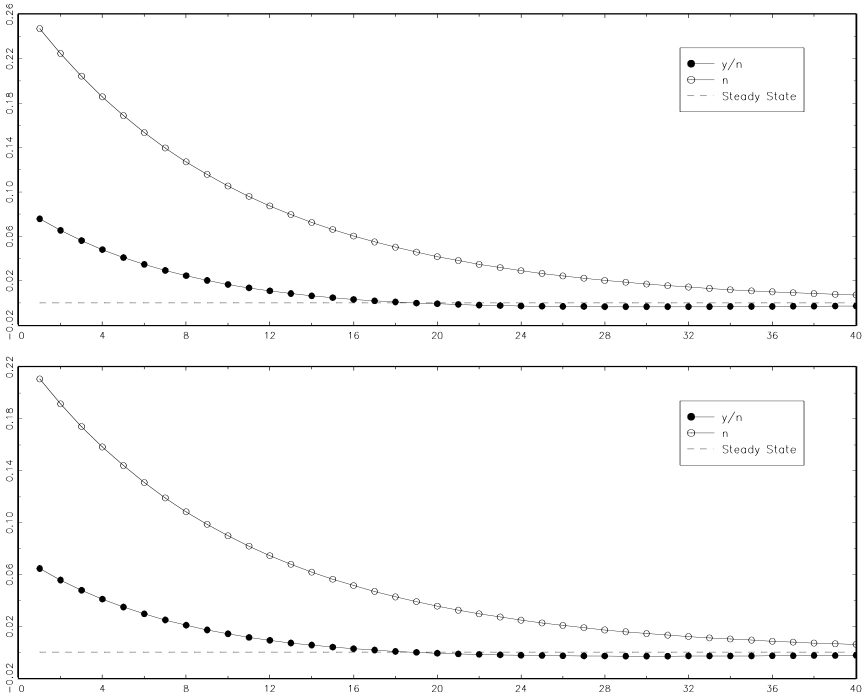

Figure 3. Impulse Responses of Productivity and Hours to a Temporary Demand Increase (top window – Δ_t, bottom window – g_t).