Variable Factor Utilization and International Business Cycles

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Abstract

When an economic boom produces high output, employment, and investment in the United States, there is usually a simultaneous boom in other industrialized countries. But, why? Answering this question is a central goal of international macroeconomics. However, multi-country dynamic equilibrium models have struggled with two major problems. The first difficulty is that the productivity shocks required by the model are implausibly large and volatile. Second, these models have difficulty explaining why factor inputs move together so closely across countries: realistic international comovement of business cycles requires implausibly high cross-country correlations of productivity shocks. This paper builds a model in which the utilization rates of capital and labor can be varied in response to shocks. We find that variable factor utilization is quite successful in (i) reducing the required size of productivity shocks; and (ii) increasing international comovement of factor inputs, with most of the improvement stemming from variable capital utilization.

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1 Introduction

When an economic boom produces high output, employment, and investment in the United States, there is usually a simultaneous boom in other industrialized countries. But, why? Answering this question is a central goal of international macroeconomics. The class of open-economy dynamic stochastic equilibrium models that have been developed to this point have had good success at explaining how business cycles can arise as an equilibrium response to "shocks" to productivity. However, multi-country models have struggled with two major problems. The first difficulty, which is a problem shared by closed-economy models, is that the productivity shocks required by the model are viewed as implausibly large and volatile. Second, the current crop of open economy models have difficulty explaining why business cycles move together so closely across countries: realistic international comovement of business cycles requires implausibly high cross-country correlations of the productivity shocks.[1]

This paper investigates whether incorporating variable utilization of factor inputs may be helpful in overcoming these difficulties. In the closed-economy models that incorporate variable factor utilization, the response to exogenous shocks is enhanced.[2] In these models, a productivity shock of a given size leads to a greater increase in output when producers can vary the utilization rate of capital and/or the intensity of labor effort. Thus, a model with variable factor utilization should require less volatility in exogenous productivity shocks in order to generate realistic levels of output volatility.

In a multi-sector or a multi-country setting, however, variable factor utilization may be even more important. The main problem with existing models of interacting economies is their prediction of negative international comovement of factor inputs. For example, these models predict that a productivity boom in the US that leads to increases in US output, investment, and employment would be accompanied by declines in investment and employment in Europe. However, this is not what we see in the data: economic booms tend to occur in most developed countries at the same time. The model mechanism that leads to this counterfactual prediction of negative international comovement is the neoclassical investment accelerator, through which

[1] See the discussion in Baxter (1995) and the references therein.

[2] See, for example, the work of Bils and Cho (1994), Burnside and Eichenbaum (1996), and King and Rebelo (1999), as well as related empirical analyses by Shapiro (1996) and Basu and Kimball (1997).

investment respond strongly to increases in productivity that are expected to be persistent. Thus, if productivity simultaneously rises in the US and in Europe, but the increase in the US is somewhat larger, the models predict a strong investment flow out of Europe and into the US There is also an important role for interactions of labor and capital in these models. When capital leaves Europe, the labor that remains there becomes less productive. This will lead to declines in labor input in Europe, which will set off another round of investment outflows because the decrease in labor input reduces the productivity of the remaining capital. The sensitivity of investment flows to small differences in the return to capital means that productivity shocks must be correlated in excess of 0.99 for the models to be able to generate positive international factor comovement. This correlation is, of course, absurdly high (a more realistic correlation is about 0.30). When firms can vary capital input via increased utilization, rather than through an increase in investment or employment as in standard models, the tendency for investment goods to flow rapidly across countries should be greatly diminished.

On the labor side, it is often thought that 'labor hoarding' is an important feature of the business cycle. We follow the work of Bils and Cho (1994) in modeling labor hoarding as variation in the effort margin–during expansions, individuals will expend more effort during each hour worked. This is 'labor hoarding' in the sense that, holding fixed the capital stock and the total number of hours worked, the marginal product of an hour worked is not constant over time. An attractive feature of this specification of 'labor hoarding' is that it allows the labor market to clear through variations in effort.

The paper is structured as follows. Section 2 presents our model of variable factor utilization which incorporates variable capital utilization and labor hoarding. Section 3 investigates the business-cycle properties of the variable utilization model. We begin by studying the effects of labor hoarding alone, and then look at the model with variable capital utilization but no labor hoarding. Finally, we study a version of the model that combines both avenues for variable factor utilization. Section 4 concludes with a summary of our results.

2 A model of variable factor utilization

There are two countries which together make up the world economy; both countries produce the same good which may be used either for consumption or investment. There is frictionless trade in the final good.[3] Trade in financial assets is limited to a non-contingent real bond.

2.1 Preferences

Our specification of preferences closely follows the work of Bils and Cho (1994) who provide an attractive specification of preferences that permits separate decisions by individuals with regard to employment, hours, and effort. We assume that individuals residing in the home country maximize expected lifetime utility, given by the following:

$$\max E_t \sum_{j=0}^{\infty} \beta^{t+j} U(C_{t+j}, N_{t+j}, H_{t+j}, E_{t+j}). \quad (1)$$

where C_t is consumption, N_t is weeks of work per period (employment), H_t is hours worked per week, E_t is effort per hour, and β is the subjective rate of time discount. Individuals in the foreign country are assumed to have the same subjective discount factor and the same utility function; they maximize:

$$\max E_t \sum_{j=0}^{\infty} \beta^{t+j} U(C^*_{t+j}, N^*_{t+j}, H^*_{t+j}, E^*_{t+j}). \quad (2)$$

We assume that the period-utility function U is separable in consumption and labor, and that the home country utility derived from consumption is given by:

$$U(C_t, N_t, H_t, E_t) = \log(C_t) - V(N_t, H_t, E_t), \quad (3)$$

with

$$V(N, H, E) = \frac{a}{1+\mu} N_t^{1+\mu} + \frac{b}{1+\varphi} N_t H_t^{1+\varphi} + \frac{1}{1+\tau} H_t N_t E_t^{1+\tau}. \quad (4)$$

There are similar expressions for the foreign country. Throughout, the functions governing preferences and technology and the parameters of these functions are assumed

[3] We study a one-good model because it is simplest and because it has the greatest potential for reduction in investment volatility through variable factor utilization. Further, as documented in Baxter (1995), the model of Backus, et al. (1994) which has different goods produced by different countries has as great a problem with comovement as the standard, one-good model. Thus, little is lost by focusing initially on a one-good, multi-location model.

to be the same across countries. This underlying symmetry allows us to focus on the stochastic elements of the model as the only reason for asymmetric choices across countries.

2.2 Technology

Home country output, denoted Y_t, is produced using capital services, S_t, and 'effective' units of labor, L_t:

$$Y_t = A_t S_t^{1-\alpha}(X_t L_t)^{\alpha}, \tag{5}$$

where A_t is the stochastic component of total factor productivity and X_t represents the level of labor-augmenting technical progress, assumed to grow at a constant, gross rate γ.

Capital services are the product of the capital stock, K_t, and the utilization rate, Z_t:

$$S_t = Z_t K_t. \tag{6}$$

Total labor input, in efficiency units, is given by the product of total hours worked, $N_t H_t$, and effort exerted per hour, E_t:

$$L_t = N_t H_t E_t. \tag{7}$$

This model can be viewed as a model of 'labor hoarding' because output per manhour will vary, holding capital services fixed, through variation in effort. Individuals will be paid the marginal product associated with their labor input measured in efficiency units, so this model of 'labor hoarding' does not entail any departure from competitive equilibrium.

We assume that increases in the utilization rate of capital are costly because higher utilization rates imply faster depreciation rates; the depreciation function is $\delta(Z_t)$, with $\delta' > 0$ and $\delta'' > 0$.[4] The stock of capital in place in the home country evolves according to

$$K_{t+1} = [1 - \delta(Z_t)]K_t + \phi(I_t/K_t)K_t. \tag{8}$$

[4] Our parameteriation of the depreciation function, which specifies only the steady state level, slope, and curvature of the depreciation function, is consistent with the following functional form:

$$\delta_t = \delta + \frac{b}{1+\zeta} Z_t^{(1+\zeta)},$$

with $b > 0$, $\delta > 0$, and $\zeta > 0$. The empirical estimates of Basu and Kimball (1997) support this type of convex depreciation function.

This specification incorporates capital adjustment costs as described by Hayashi (1982) and employed by Baxter and Crucini (1995). The adjustment cost function is strictly positive with $\phi' > 0$ and $\phi'' < 0$. Firms choose an optimal level of utilization, as well as labor and capital inputs. When selecting an optimal rate of utilization, firms must weigh the benefits of greater output against the costs of greater depreciation. There are foreign country analogues to eqns. (5)-(8); see the Appendix for more detail.

2.3 Financial market structure

International trade in financial assets is limited to one-period, real discount bonds. These bonds sell at price $P_t^B = (1 + r_t)^{-1}$, where r_t is the world interest rate. Letting B_{t+1} denote the quantity of bonds purchased by residents of the home country at date t, the asset-accumulation equation for the home country is:

$$B_t + Y_t \geq C_t + I_t + P_t^B B_{t+1}. \tag{9}$$

The foreign country analogue is:

$$B_t^* + Y_t^* \geq C_t^* + I_t^* + P_t^B B_{t+1}^*. \tag{10}$$

We assume that bonds are in zero net supply, so world bond market clearing satisfies

$$\pi B_t + (1 - \pi) B_t^* = 0, \tag{11}$$

where π is the fraction of the world population residing in the home country.

2.4 Model calibration

This sub-section describes the calibration of our model. The time period is a quarter of a year.

Preferences The parameters μ, φ, and τ in equation (4) govern the compensated elasticities of the employment, hours, and effort responses to real wage movements. The compensated elasticity of hours per week with respect to the real wage is equal to $1/\varphi$. Bils and Cho (1994) cite research by Pencavel (1986) and Killingsworth and Heckman (1986) that suggests a compensated hours-per-week elasticity of 0.5, corresponding to $\varphi = 2$, although Bils (1987) estimated a somewhat higher hours-per-week supply elasticity of about 0.7. Prescott (1986) assumes a higher value of 2.0 for the compensated elasticity of labor supply (corresponding to $\varphi = 0.5$). In Prescott's model, there is no variation in employment, so this higher elasticity is useful in generating higher volatility in total labor input where all of the actual adjustment is on the hours-per-week margin. In our baseline model, we choose $\varphi = 2$. In our sensitivity analysis, we also report results for $\varphi = 1$.

Bils and Cho (1994) use PSID data to estimate that the standard deviation of changes in weeks relative to changes in hours is $(1+\varphi)/\mu = 1.91$, which is the value we adopt in our baseline model and also use throughout the sensitivity analysis. For $\varphi = 2$, this implies $\mu = 1.57$.

The parameter τ determines the elasticity of the effort response. Specifically, the elasticity of effort with respect to the workweek is $\varphi/(1+\tau)$. Schor (1987) uses data from time-and-motion studies and estimates a value of this elasticity that ranges from $\varphi/(1+\tau) = 0.516$ to $\varphi/(1+\tau) = 0.597$, with a standard error in each case of about 0.14. With $\varphi = 2$, $\varphi/(1+\tau) = 0.5$ implies $\tau = 3$, which is the value we use in our baseline model. In our sensitivity analysis, we also experiment with an effort elasticity at the upper end of the 95% confidence interval estimated by Schor. Finally, individuals' subjective discount factor is set equal to $\beta = 0.984$.

Technology Labor's share is equal to $\alpha = 0.58$, and the gross growth rate of labor-augmenting technical change is $\gamma_X = 1.004$. The adjustment cost function $\phi(i/k)$ is parameterized as follows. We set $\phi(i/k) = 1$ and $\phi'(i/k) = 1$ in order to ensure that the steady state of the model is unaffected by incorporating adjustment costs. Given $\phi(i/k) = \phi'(i/k) = 1$, the elasticity of (i/k) with respect to movements in Tobin's q is governed by the curvature of the adjustment cost function, $\phi''(i/k)$. There are no micro studies that can tell us the appropriate setting for this parameter. However, it has been noted in past research that this elasticity primarily affects the volatilities of investment (and, of course, consumption) relative to output. As in Baxter and Crucini (1993, 1995) and Baxter (1995), we can use information on the relative volatility of investment to restrict the value of this elasticity, setting $\eta = 15$. As in prior studies, this value of the adjustment cost elasticity means that investment is about 3 times as volatile as output in the absence of variable factor utilization.

Incorporating variable utilization introduces a new parameter, ζ, which represents the elasticity of marginal depreciation with respect to the utilization rate:

$$\zeta = \frac{Z\delta''(Z)}{\delta'(Z)} > 0.$$

Our parameterization of ζ is guided by the empirical work of Basu and Kimball (1997), who estimate a log-linear production function incorporating variations in both capital utilization and effort for a panel of US firms from 21 manufacturing industries for the period 1949-1985. They estimate ζ to be approximately unity. They stress, however, that "the data are not very informative" about this parameter. The 95% confidence interval of $[-0.2, 2]$ indicates that the data cannot reject even infinitesimally small values of ζ, although the negative values should be eliminated on purely economic grounds. In our baseline model, we specify $\zeta = 1$. In our sensitivity analysis, we also investigate the effects of reducing the elasticity of marginal depreciation with respect to utilization, by studying the effects of $\zeta = 0.10$ and $\zeta = 0.05$.

Productivity The exogenous process for de-meaned, detrended productivity is specified as a bivariate $VAR(1)$:

$$\begin{bmatrix} \log A_t \\ \log A_t^* \end{bmatrix} = \begin{bmatrix} \rho & \nu^* \\ \nu & \rho^* \end{bmatrix} \begin{bmatrix} \log A_{t-1} \\ \log A_{t-1}^* \end{bmatrix} + \begin{bmatrix} \varepsilon_t \\ \varepsilon_t^* \end{bmatrix}. \tag{12}$$

Many researchers have attempted to estimate the parameters of this process; see, for example, the work of Backus, Kehoe, and Kydland (1993), Reynolds (1993), and Baxter and Crucini (1995). It has proved impossible to estimate the parameters of (12) with much precision, even if one is willing to abstract from variable utilization, so that the standard "Solow residual" measure of productivity:

$$\log SR_t = \log Y_t - (1-\alpha)K_t - \alpha N_t \tag{13}$$

is also the correct measure of true productivity, A_t.

These prior studies have suggested several qualitative features of the standard "Solow residual" measure of the productivity shocks. First, the shock process is highly persistent; Baxter and Crucini (1995) show that one cannot reject the hypothesis that the productivity shocks follow a near-unit-root processes. Second, the innovations to productivity are positively correlated: $cov(\varepsilon_t, \varepsilon_t^*) > 0$. It is less clear whether there is transmission of shocks from one country to another over time ($\nu > 0$ and/or $\nu^* > 0$); while the point estimates of Backus, Kehoe and Kydland do suggest transmission, especially from the US to other countries, the results of Reynolds (1993) and Baxter and Crucini (1995) find that the transmission parameters are not statistically significant. In light of these results, we parameterize our productivity process as a near-unit-root process without spillovers, $\rho = \rho^* = 0.999$; $\nu = \nu^* = 0$. We specify that $corr(\varepsilon_t, \varepsilon_t^*) = 0.258$, which is consistent with estimates obtained in the various empirical studies discussed above. This parameterization of the productivity process will be used for all of the model variants that we study.

It remains to specify the variances of the innovations, ε_t and ε_t^*. The usual procedure (see, for example, Backus, Kehoe, and Kydland (1993) or Baxter (1995)) is to estimate the innovation variances and then calibrate the model using this estimate. In the present paper, however, we use a different approach. In each variant of the model that we study, we will calibrate the innovation variance of the productivity shocks so that the volatility of output in the model economy exactly matches the volatility of output observed in US data. This will allow us to easily evaluate how the required volatility of the productivity shocks changes as we incorporate labor hoarding and variable capital utilization.

Finally, the model is solved using the solution algorithm described in King and Watson (1998); the details are contained in the Appendix.

3 Variable factor utilization and business cycle moments

This section explores how variable factor utilization affects the business-cycle moments generated by our two-country international business cycle model. We begin by reviewing the properties of the data and the moments generated by the baseline model without variable capital or labor utilization. We then explore how the model's predictions are altered when we allow (i) labor hoarding alone; (ii) variable capital utilization alone; and (iii) labor hoarding and variable capital utilization together.

3.1 The data and the baseline model

Table 1 shows the business-cycle properties of the data together with the predictions of a baseline model that abstracts from variable factor utilization. The business-cycle components of the data are extracted using the $BP_{12}(6, 32)$ band-pass filter described in Baxter and King (1999). The business-cycle properties of US data are well-known, so we review these only briefly. Consumption is less volatile than output, while investment is approximately three times as volatile as output. We present statistics for employment, hours per week, and total hours separately, since our model of labor hoarding will have implications for each of these variables. In US data, the percentage variation in employment is nearly four times as volatile as variation in hours per week. Real wages are about half as volatile as output, and net exports are about one-quarter as volatile as output.

Our model with variable capital utilization will have predictions for the behavior of the capital stock, the rate of capital utilization, and the rate of capital services. Unfortunately, none of these variables is measured well in the data. A measure of the utilization rate is published by the Board of Governors of the Federal Reserve System, but this is a measure of the "output gap" rather than being a direct measure of the services supplied by the capital stock. An empirical measure of capital services is not available.

All the macro aggregates that we consider are highly autocorrelated, with first-order autocorrelation coefficients ranging from 0.88 to 0.97. Consumption, investment, the labor variables, the utilization rate, and real wages are all positively correlated with output. The capital stock is approximately acyclical, while net exports are countercyclical.

Cross-country properties of the data are shown in the bottom panel of Table 1. The key stylized facts are as follows. Outputs are positively correlated across countries, as are consumptions, although cross-country consumption correlations are well-known to be smaller than corresponding cross-country output correlations in most cases. The cross-country correlation of investment tends to be positive, as does the cross-country correlation of labor input (the empirical measure reported here is employment).

To construct moments for the baseline model without variable factor utilization, we choose the variability of the productivity shock process ($var(\varepsilon_t)$) so that the standard deviation of output in the model exactly matches the empirical standard deviation of output: 1.69% per quarter. In this model, this means that the (filtered) standard deviation of the productivity shock is 1.54% per quarter–the productivity shock is 0.91 times as volatile as output. The Solow residual is computed as in equation (13); this is equivalent to the true productivity shock when there is no variability in factor utilization.

In our baseline model, consumption is nearly as volatile as output, while relative consumption volatility is somewhat lower in US data.[5] Investment in our model is about three times as volatile as output, which is a bit higher than the relative volatility exhibited by the data. In the baseline model, all of the variation in total hours occurs through variation in hours per week. Compared with the data, the variation in hours per week is too high, while the variation in total hours is too low. Partly, the low variation in total hours reflects the absence of employment fluctuations in the model; partly, it reflects the fact that our baseline model has an elasticity of hours with respect to the real wage that is one-quarter of the size of the elasticity typically used in "real business cycle" models. Our model predicts a relatively low correlation of hours with output, compared with the data. At the same time, the predicted correlation of real wages with output is much too high, relative to the data. The model correctly predicts that net exports are negatively correlated with output, and the magnitude of this correlation is also approximately correct.

Looking at cross-country correlations, we find that the model predicts that output correlations exceed consumption correlations, which is a well-known feature of the international data. Both correlations are within the range of observations for OECD countries. However, the output correlation is on the high side of its range: the model predicts a cross-country output correlation of 0.61; the range of correlations in the data is [-0.35, 0.81] with a median of 0.29. The consumption correlation is on the low side of its range, with a model prediction of -0.37. In the data, consumption correlations are in the range [-0.62,0.67] with a median of 0.12.

Strikingly, the model predicts that investment and labor input will be negatively correlated across countries: 0.41 for investment, -0.34 for hours. This pattern is a common feature of most international business cycle models, yet it is not the pattern observed in the data. The median cross-country investment correlation in the data is 0.25; for employment, the median correlation is 0.26, and for hours, the median correlation is 0.43. Thus, one important goal of this research is to determine whether variable factor utilization can improve the predictions of our model for the cross-country comovement of factor inputs.

As noted earlier, the productivity shock must be 0.91 times as volatile as output in order for the model to match the observed volatility of output. This shock is highly

[5] However, the relative volatility of consumption is low in the US relative to other countries. In Japan, for example, consumption is about as volatile as output. See Baxter (1995) for more details.

persistent, with first-order autocorrelation of 0.90; it is also highly correlated with output, with a correlation coefficient of 0.93. The high volatility of the productivity shock is frequently viewed as a problem for this class of models, as it implies a significant probability of technical regress. Further, the very high required persistence of the shock is evidence of weak internal propagation mechanisms in these models. Thus, a second goal of this paper is to determine whether variable factor utilization can be successful in reducing the volatility and persistence of the productivity shock that is required for the model to mimic the salient business-cycle features of the data.

3.2 Labor hoarding

This section explores the effect of introducing variable labor utilization via the labor hoarding model of Bils and Cho (1994). In order to explore the effect of reasonable perturbations of the parameters of the labor hoarding model, Table 2 presents moments for three cases.

Case 1 is the Bils-Cho parameterization, with $\varphi = 2$, $\mu = 1.57$, and $\tau = 3$.

Case 2 increases the compensated hours elasticity to 1 by setting $\varphi = 1$. We continue to assume that the standard deviation of changes in weeks relative to changes in hours is $(1+\varphi)/\mu = 1.91$; for $\varphi = 1$, this implies $\mu = 1.05$. The elasticity of effort with respect to the workweek is $\varphi/(1+\tau)$, which was estimated to approximately 0.5. With $\varphi = 1$, $\varphi/(1+\tau) = 0.5$ implies $\tau = 1$.

Case 3 increases the effort elasticity relative to Case 1, setting $\varphi = 1$, $\mu = 1.05$, and $\tau = 0.14$. This implies an effort elasticity of $\varphi/(1+\tau) = 0.88$ which is at the upper end of the 95% confidence interval implied by the estimates of Schor (1987).

In the Bils-Cho parameterization, Case 1, the relative volatilities of consumptionand investment are both too high, as was true in the baseline model. The Bils-Cho parameterization has trouble matching the empirical volatility of employment (the model predicts 0.44% per quarter, while the data show 1.44%), and the predicted volatility of hours is also too low at 0.19% per quarter, compared with 0.38% in the data. These two factors combined mean that the model's prediction for the volatility of total hours (0.57%) is only about a third as large as in the data (1.69%). As in the baseline model, real wage volatility continues to be too high, as does the volatility of net exports.

The hours elasticity used by Bils and Cho is substantially smaller than the elasticity commonly used in other quantitative macro models (see, e.g., Prescott (19xx)).

When we increase the hours elasticity to 1 (Case 2), the volatility employment rises, although not by enough to match the data. The volatility of hours rises as well, and approaches the level found in the data. The volatility of effort rises as well. As a combination of these three effects, the volatility of effort. The volatility of effective labor jumps sharply, from 0.66% per quarter to 1.02% per quarter. The volatility of real wages also rises, which is not desirable, as real wages were already too volatile in the Bils/Cho case (case 1). There is a small increase in the volatility of net exports which, again, is not desirable. Case 3, which combines a high hours elasticity with a high effort elasticity leads to further increases in volatility in employment, hours, and effort. While the hours volatility is approximately correct in case 3, the increase in volatility of employment still leaves the model to predict less than half the employment volatility seen in the data.

One motivation for introducing variable factor utilization was to reduce the required volatility of productivity shocks, relative to the baseline models. However, introducing labor hoarding in the particular form chosen here has very little effect on the volatility of productivity shocks that is required to match the volatility of output. In the benchmark economy (Table 1), the productivity shock was 0.91 times as volatile as output. The Bils/Cho specification, Case 1, requires productivity to be 0.92 times as volatile as output. Increasing the elasticities of various components of labor input leads to slight reductions in the required relative volatility of productivity: 0.90 in case 2, and 0.87 in case 3.

Table 2 does not report predictions for first-order autocorrelation. We found that there was no effect (at 2 significant digits) on the model's autocorrelation properties of introducing labor hoarding, regardless of which case is considered. Thus, we conclude that the Bils/Cho model of labor hoarding does not reduce the required volatility or persistence of productivity shocks in our two-country model.

Varying the labor hoarding parameters across the three cases leads to relatively small effects on the within-country correlations with output. In all three cases, the model produces correlations of employment and hours with output that are too low, compared with the data. Further, as we move from case 1 to case 3, the consumption-output correlation and the investment-output correlation become implausibly low, while the correlation between net exports and output–which is approximately correct in the Bils/Cho setup–rises toward zero.

Looking at the cross-country correlations, we find that the Bils-Cho version of the labor hoarding model shares all the difficulties of the baseline model: output correlations that are a bit too high, and negative cross-country correlations of consumption, investments, and labor inputs. As we increase the hours elasticity (Case 2) and the hours and effort elasticities together (Case 3), the model's predicted correlation of investments rises, but never becomes positive. Worse, labor input correlations grow even more strongly negative as we move from Case 1 to Case 3.

Overall, we conclude that incorporating "labor hoarding" along the lines suggested by Bils and Cho does not lead to a significant alteration of the predictions generated by our two-country macro model. First, productivity shocks must still be nearly as volatile as output and nearly as autoccorelated, if the model is to be able to match volatility and persistence properties of the macro data. Second, the model with labor hoarding continues to predict strong, negative cross-country correlation between factor inputs.

3.3 Variable capital utilization

This sub-section explores the implications of variable capital utilization for the business-cycle properties of the model. We consider three cases,which correspond to different values of ζ, the parameter that governs the elasticity of the utilization response (lower values of ζ imply a more-elastic response). The first case sets $\zeta = 1$, which is the Basu-Kimball (1997) point estimate. We consider two additional cases, corresponding to higher utilization elasticities: $\zeta = 0.10$, and $\zeta = 0.05$. Given the imprecision in the Basu-Kimball estimates, both of these alternative values of ζ are within the 95% confidence interval. The results for these three cases are presented in Table 3.

A major finding is that the variable capital utilization model dramatically reduces the required volatility of productivity shocks. Recall that the baseline model (Table 1) required productivity shocks that were 91% as volatile as output. The highest-elasticity case of the labor hoarding model reduced this number to just 87%. By contrast, Case 1 of the utilization model requires that productivity shocks are only 73% as volatile as output. With higher utilization elasticities, the required volatility of productivity shocks falls to 57% of output volatility (Case 2), and 55% (Case 3). Although variable capital utilization is successful in reducing the required volatility of productivity shocks, there was not effect on the required persistence of the shock. We found that the autoregressive properties of the model were unchanged, relative to the benchmark model, by incorporating variable utilization. For this reason, we do not report these autocorrelations for the variable-utilization model.

Comparing Cases 1-3, we find that increasing the elasticity of the utilization response (i.e., decreasing ζ), affect the within-county characteristics of business cycles along several dimensions. First, the relative volatilities of consumption, the capital stock and net exports all decline to levels more consistent with the data. However, more-elastic capital utilization works to reduce investment volatility and hours volatility, which is not desirable as the model already underpredicted the volatility of these variables. The correlations of the macro aggregates with output change with increases in the elasticity of utilization: increasing elasticity raises the correlation of output with consumption, investment, hours, and real wages, which is undesirable since many of these correlations were too high to begin with. However, increasing the utilization elasticity reduces the correlation between output and the capital stock, which is a move in the right direction.

Introducing variable capital utilization leads to remarkable improvement in the cross-country correlations of consumption, investment, and labor input. Specifically, increases in the utilization elasticity lead to an increase in the cross-country consumption correlation, to the point where this correlation is now very consistent with the data. Output correlations decrease slightly as the utilization elasticity rises, but in all three cases, consumption correlations are smaller than output correlations, as is true in the data.

The most important effect of allowing variable utilization is the effect on the cross-country correlations of factor inputs. Increasing the utilization elasticity increases the cross-country correlations of investment, hours, and real wages. In Cases 2 and 3, the cross-country correlations of investment and hours are positive, and are consistent with the range observed in the data. Further, the cross-country correlation of real wages in the baseline model was -0.16, compared with 0.43 in the data. With variable utilization, the real wage correlation rises to a level close to that to the level observed in the data (0.25 in case 2). Neither the standard model, nor the model with labor hoarding alone, could produce this pattern of positive cross-country correlation in hours, investment, or real wages..

Finally, the cross-country correlation of the standard Solow residual is higher than the cross-country correlation of the true productivity shocks; this discrepancy is higher with more-elastic utilization. This finding reflects the fact that the capital services are positively correlated across countries when utilization is variable;

these capital services are included in the standard Solow residual but not in the true productivity residual.

3.4 Combining labor hoarding and variable capital utilization

This sub-section explores the effects of combining labor hoarding with variable capital utilization. In the prior two sub-sections, we found that labor hoarding alone did little to change the properties of the basic model, while variable capital utilization led to many significant improvements. Although labor hoarding was not important in isolation, it may have significant effects when combined with variable capital utilization.

Table 4 presents the results obtained in a model that combines labor hoarding with variable capital utilization. Three cases are presented. Case 1, which we view as a "benchmark" case, uses the Bils-Cho parameterization of labor hoarding (Case 1 in Table 2) together with the Basu-Kimball point estimate of $\zeta = 1$ for the depreciation elasticity (Case 1 in Table 3). Case 2, which we term the "moderately elastic case," uses the parameters from Case 2 in Tables 2 and 3. Case 3, the "highly elastic case," uses Case 3 parameters from Tables 2 and 3.

Overall, we find that combining labor hoarding with variable capital utilization leads to model predictions that are very similar to those obtained in a model with variable capital utilization alone. Notably, the reduction in the required volatility of productivity is virtually the same in the combined model as in the utilization-only model.

The few differences are as follows. First, adding labor hoarding to the variable-capital-utilization model leads to lower correlations between total hours and output, which is undesiragle as this correleation is quite high in the data. On the positive side, incorporating labor hoarding also generally improves the correlation between net exports and output. The cross-country correlations of factor inputs remain positive in cases 2 and 3, as in the case with variable capital utilization alone. The cross-country correlation of hours appears very sensitive to the parameterization of capital utilizaiton and the incorporation of labor hoarding. Specifically, the hours correlation rises with increases in the utilization elasticity in the utilization-only model of Table 3. However, as we move from Cases 1 to 3 in the combined model of Table 4, the hours correlation first rises then falls.

4 Summary and conclusion

This paper explores the importance of variable utilization of factor inputs for open economy business cycles. We incorporate labor hoarding through a model suggested by Bils and Cho (1994), and we incorporate variable capital utilization through a standard depreciation-in-use specification. We study the effects on model predictions of each of these modifications separately, and then study the effect of combining the two margins for variable factor utilization.

Our main findings are as follows. Labor hoarding alone has virtually no effect on the model's predictions, compared with a standard two-country business cycle model. By contrast, variable capital utilization improves the predictions of the model along two important dimensions. First, variable capital utilization reduces the required volatility of the productivity shock by a very significant $20\% - 40\%$. Second, variable capital utilization is very effective in strengthening the model's predicted cross-country correlations between factor inputs. Finally, we found that combining labor hoarding with variable capital utilization has little effect on the model's predictions, compared with the model with variable utilization alone.

A Data Appendix

This appendix provides documentation for the data used to compute the statistics in Table 1.

A.1 Within Country Statistics

All of the statistics in Table 1 for within country business cycles are based on the following US data taken from Citibase.

1. OUTPUT: Citibase Series: GDPQ / Quarterly 1947:1 to 1998:4 / Gross Domestic Product

2. CONSUMPTION: Citibase Series: GCQ / Quarterly 1947:1 to 1998:4 / Personal Consumption Expenditures, Total

3. INVESTMENT: Citibase Series: GIFQ / Quarterly 1947:1 to 1998:4 / Fixed Investment, Total

4. EMPLOYMENT: Citibase Series: LPNAG / Monthly 1947:1 to 1999:2 / Employees on Nonagricultural Payrolls, Total (Thousands, SA)

5. HOURS PER WEEK: Citibase Series: LW / Monthly 1964:1 to 1999:2 / Average Weekly Hours of Production Workers: Total Private (SA)

6. TOTAL HOURS: Citibase Series: LPMHU / Monthly 1947:1 to 1999:2 / Employee Hours in Nonagricultural Establishments (Billions of hours, SAAR)

7. CAPITAL: KQ / Quarterly 1947:1 to 1998:4 / Quarterly series is constructed using an annual capital series and quarterly investment series. Taken from Stock and Watson [1998].

8. UTILIZATION RATE: Citibase Series: IPXMCA / Monthly 1948:1 to 1999:2 / Capacity Utilization Rate: Manufacturing, Total (% of Capacity, SA)

9. REAL WAGES: Citibase Series: LBCPU7 / Quarterly 1947:1 to 1998:4 / Real Compensation per Hour: Nonfarm Business (1982=100, SA)

10. NET EXPORTS:

(a) Exports: Citibase Series: GEXQ / Quarterly 1947:1 to 1998:4 / Exports of Goods and Services

(b) Imports: Citibase Series: GIMQ / Quarterly 1947:1 to 1998:4 / Imports of goods and services

(c) Net exports: (GEXQ-GIMQ)/GDPQ

11. SOLOW RESIDUAL: Computed as follows:

$$log(gdpq) - 0.58 * log(lpmhu) - (1 - 0.58) * log(kq)$$

A.2 Cross-country statistics

The cross-country correlations in Table 1 are based on the following series from the OECD 1996 Statistical Compendium. The series number for each variable is in parentheses.

A.2.1 Output

1. US (421090006): Gross Domestic Product / constant prices / seasonally adjusted / millions of 1992 US$ / quarterly 1960:1 - 1994:4 / Department of Commerce

2. Canada (440010007): Gross Domestic Product / constant prices / seasonally adjusted / millions of 1986 CAN$ / quarterly 1960:1 - 1994:4 / Statistics Canada

3. France (141040006): Gross Domestic Product / constant prices / seasonally adjusted / millions of 1980 Francs / quarterly 1970:1 - 1994:4 / INSEE

4. Germany (132032018): Gross Domestic Product / constant prices / seasonally adjusted / millions of 1991 DM / quarterly 1960:1 - 1994:4 / Statictisches Bundesamt

5. Italy (163010008): Gross Domestic Product / constant prices / seasonally adjusted / millions of 1985 Lire / quarterly 1970:1 - 1994:4 / ISTAT

6. Japan (461027006): Gross Domestic Product / constant prices / seasonally adjusted / millions of 1990 YEN / quarterly 1960:1 - 1994:4 / Economic Planning Agency

7. UK (260100107): Gross Domestic Product at Mark Pr. / constant prices / seasonally adjusted / millions of 1990 Pounds / quarterly 1960:1 - 1994:4 / Central Statistical Office

A.2.2 Consumption

1. US (421010206): Personal Consumption Expenditures / constant prices / seasonally adjusted / millions of 1992 US$ / quarterly 1970:1 - 1996:1 / Department of Commerce

2. Canada (440010107): Personal Consumption Expenditure / constant prices / seasonally adjusted / millions of 1986 CAN$ / quarterly 1970:1 - 1996:1 / Statistics Canada

3. France (141080006): Private Consumption Expenditure / constant prices / seasonally adjusted / millions of 1980 Francs / quarterly 1970:1 - 1996:1 / INSEE

4. Germany (N/A)

5. Italy (163011108): Private Consumption / constant prices / seasonally adjusted / millions of 1985 Lire / quarterly 1970:1 - 1996:1 / ISTAT

6. Japan (461021006): Private Final Consumption Expenditure / constant prices / seasonally adjusted / millions of 1990 YEN / quarterly 1970:1 - 1996:1 / Economic Planning Agency

7. UK (260100307): Private Current Expenditure / constant prices / seasonally adjusted / millions of 1990 Pounds / quarterly 1970:1 - 1996:1 / Central Statistical Office

A.2.3 Investment

1. US (421017006): Fixed Investment / constant prices / seasonally adjusted / millions of 1992 US$ / quarterly 1960:1 - 1995:3 / Department of Commerce

2. Canada (440010307): Gross Fixed Capital Formation / constant prices / seasonally adjusted / millions of 1986 CAN$ / quarterly 1960:1 - 1995:3 / Statistics Canada

3. France (141043006): Gross Fixed Capital Formation / constant prices / seasonally adjusted / millions of 1980 Francs / quarterly 1970:1 - 1995:3 / INSEE

4. Germany (13102300R): Gross Fixed Capital Formation WS / constant prices / millions of 1991 DM / quarterly 1960:1 - 1995:3 / West Germany Statistiches Bundesamt

5. Italy (163012007): Gross Fixed Capital Formation / constant prices / seasonally adjusted / millions of 1985 Lire / quarterly 1970:1 - 1995:3 / ISTAT

6. Japan (461023006): Gross Domestic Fixed Capital Formation / constant prices / seasonally adjusted / millions of 1990 Yen / quarterly 1960:1 - 1995:3 / Economic Planning Agency

7. UK (26010050L): Gross Domestic Fixed Capital Formation / constant prices / millions of 1990 Pounds / Quarterly 1960:1 - 1995:3 / Central Statistical Office

A.2.4 Employment

1. US (42426602): United States / Total Employment / 1990=100 / quarterly 1960:1 - 1996:1 / Bureau of Labor Statistics

2. Canada (44426602): Canada / Total Employment / 1990=100 / quarterly 1960:1 - 1996:1 / Statistics Canada

3. France (14426602): France / Total Employment / 1990=100 / quarterly 1981:1 - 1996:1 / Statistical Office of France, INSEE

4. Germany (12426502): Germany / Total Employment / 1990=100 / quarterly 1981:1 - 1996:1 / Federal Statistical Office of Germany

5. Italy (16426502): Italy / Total Employment / 1990=100 / quarterly 1960:1 - 1996:1 / National Institute of Statistics, ISTAT

6. Japan (46426402): Japan / Total Employment / 1990=100 / quarterly 1960:1 - 1996:1 / Ministry of Labour

7. UK (26426502): United Kingdom / Total Employment / 1990=100 / quarterly 1960:1 - 1996:1 / Office for National Statistics

A.2.5 Hours per week

1. US (42429308): Weekly hours of work / Labour - other hours / quarterly 1961:1 - 1995:4 / Bureau of Labor Statistics
2. Canada (44429308): Weekly hours of work / Labour - other hours / quarterly 1961:1 - 1995:4 / Statistics Canada
3. France (n/a)
4. Germany (12429302): Weekly hours of work / Labour - other / 1990=100 / quarterly 1961:1 - 1995:4 / Federal Institute of Labour
5. Italy (n/a)
6. Japan (46429202): Monthly hours of work / Labour - other / 1990=100 / quarterly 1961:1 - 1995:4 / Ministry of Labour
7. UK (26429312): Weekly hours of work s.a. / Labour - other / 1990=100 / quarterly 1961:1 - 1995:4 / Office for National Statistics

A.2.6 Wages

1. US (42431502): Hourly earnings / Wages / 1990=100 / quarterly 1963:1 - 1995:4 / Bureau of Labor Statistics
2. Canada (44431502): Hourly earnings / Wages / 1990=100 / quarterly 1963:1 - 1995:4 / Statistics Canada
3. France (14431102): Hourly earnings (manufacturing) / 1990=100 / quarterly 1963:1 - 1995:4 / Ministry of Labour
4. Germany (12431502): Hourly earnings / Wages / 1990=100 / quarterly 1963:1 - 1995:4 / Federal Statistical Office of Germany
5. Italy (16431102): Hourly rates / Wages / 1990=100 / quarterly 1963:1 - 1995:4 / National Institute of Statistics, ISTAT
6. Japan (46432202): Monthly earnings / Wages / 1990=100 / quarterly 1963:1 - 1995:4 / Ministry of Labour

7. UK (26431902): Weekly earnings: employees / Wages / 1990=100 / quarterly 1963:1 - 1995:4 / Office for National Statistics

A.2.7 Solow residual

The Solow residual for each country is computed as

$$\log(SR_t) = \log(Y_t) - sn * \log(EMP_t),$$

where SR_t is the Solow residual, Y_t is output, sn is labor's share (0.58) and EMP_t is employment.

B Solution method

The competitive equilibrium for this economy can be found as the solution to the following Lagrangian problem, where variables are as defined in the text, except that lowercase variables have been deflated by γ, the exogenous growth in labor-augmenting technical , and where $\widetilde{\beta}$ denotes to the subjective discount factor appropriate for this transformed economy:

$$\begin{aligned}
\mathcal{L} &= \max_{\{c_t,n_t,h_t,e_t,l_t,s_t,k_{t+1},z_t,i_t\}} E_0\pi \sum_{t=0}^{\infty} \widetilde{\beta}^t \{u(c_t,n_t,h_t,e_t) + (1-\pi)u(c_t^*,n_t^*,h_t^*,e_t^*) \quad (14)\\
&\quad +w_t(n_t h_t e_t - l_t) + w_t^*(n_t^* h_t^* e_t^* - l_t^*)\\
&\quad +\lambda_t[(1-\delta(z_t))k_t - (\gamma k_{t+1} - \phi(i_t/k_t)k_t)]\\
&\quad +\lambda_t^*[(1-\delta(z_t^*))k_t^* - (\gamma k_{t+1}^* - \phi(i_t^*/k_t^*)k_t^*)]\\
&\quad +q_t(k_t z_t - s_t) + q_t^*(k_t^* z_t^* - s_t^*)\\
&\quad +p_t(b_t + A_t F(s_t,l_t) - c_t - i_t - P_t^B \gamma b_{t+1})\\
+ &\quad p_t^*(b_t^* + A_t^* F(s_t^*,l_t^*) - c_t^* - i_t^* - P_t^B \gamma b_{t+1}^*)\}
\end{aligned}$$

B.1 Efficiency conditions

The first order conditions for home-country choice variables are as follows, where $\Psi(x) \equiv [\phi(x) - xD\phi(x) + (1-\delta)]$:

$$c_t : D_1 u(c_t,n_t,h_t,e_t) - p_t = 0 \tag{15}$$

$$n_t : D_2 u(c_t,n_t,h_t,e_t) + w_t h_t e_t = 0 \tag{16}$$

$$h_t : D_3u(c_t, n_t, h_t, e_t) + w_t n_t e_t = 0 \tag{17}$$

$$e_t : D_4u(c_t, n_t, h_t, e_t) + w_t n_t h_t = 0 \tag{18}$$

$$w_t : l_t - n_t h_t e_t = 0 \tag{19}$$

$$i_t : \lambda_t D\phi(i/k) - p_t = 0 \tag{20}$$

$$s_t : p_t A_t D_1 F(s_t, l_t) - q_t = 0 \tag{21}$$

$$l_t : p_t A_t D_2 F(s_t, l_t) - w_t = 0 \tag{22}$$

$$k_{t+1} : \beta E_t(\lambda_{t+1}\Psi(i_{t+1}/k_{t+1}) + q_{t+1}) - \gamma\lambda_t = 0 \tag{23}$$

$$\lambda_t : [(1 - \delta(z_t))k_t - (\gamma k_{t+1} - \phi(i_t/k_t)k_t)] = 0 \tag{24}$$

$$q_t : k_t z_t - s_t = 0 \tag{25}$$

$$z_t : q_t - \delta'(z_t)\lambda_t = 0 \tag{26}$$

$$b_{t+1} : \beta p_{t+1} - P_t^B \gamma p_t = 0 \tag{27}$$

$$p_t : b_t + A_t F(s_t, l_t) - c_t - i_t - P_t^B \gamma b_{t+1} = 0 \tag{28}$$

There are similar equations for home-country variables. World bond market clearing is given by

$$\pi b_t + (1 - \pi) b_t^* = 0. \tag{29}$$

The world general equilibrium is solved by incorporating the bond market clearing equation with the home accumulation equation, and imposing the equilibrium condition $P_t^B = \beta E_t(p_{t+1}/\gamma p_t) = \beta E_t(p_{t+1}^*/\gamma p_t^*)$in the accumulation equations. The resulting system of equations is then linearized around the deterministic steady state (as in the following subsection) and solved using the algorithm of King and Watson (1995).

B.2 The linearized system

The linearized versions of the home country equations are as follows:

$$-\widehat{c}_t = \widehat{p}_t \tag{30}$$

$$\mu\widehat{n}_t = (1 + \varphi)\widehat{h}_t$$

$$\varphi\widehat{h}_t = (1 + \tau)\widehat{e}_t$$

$$\tau \widehat{e}_t - \widehat{w}_t = 0$$

$$\widehat{l}_t = \widehat{n}_t + \widehat{h}_t + \widehat{e}_t \tag{31}$$

$$\xi(\widehat{i}_t - \widehat{k}_t) = \widehat{p}_t - \widehat{\lambda}_t \tag{32}$$

$$\xi_{kk}\widehat{s}_t + \xi_{kL}\widehat{l}_t + \widehat{A}_t + \widehat{p}_t = \widehat{q}_t \tag{33}$$

$$\xi_{LL}\widehat{l}_t + \xi_{Lk}\widehat{s}_t + \widehat{p}_t + \widehat{A}_t = \widehat{w}_t \tag{34}$$

$$\beta\Psi(.)\widehat{\lambda}_{t+1} + \beta\frac{i}{k}D\Psi(.)(\widehat{i}_{t+1} - \widehat{k}_{t+1}) - (\beta\Psi(.) - \gamma)\widehat{q}_{t+1} + \gamma\widehat{\lambda}_t = 0 \tag{35}$$

$$\gamma\widehat{k}_{t+1} + \Psi\widehat{k}_t + \frac{i}{k}D\phi(.)\widehat{i}_t = \frac{q}{\lambda}\widehat{z}_t \tag{36}$$

$$\widehat{z}_t + \widehat{k}_t = \widehat{s}_t \tag{37}$$

$$\frac{1}{\zeta_{\delta z}}(\widehat{q}_t - \widehat{\lambda}_t) = \widehat{z}_t \tag{38}$$

$$\beta\frac{\pi - 1}{\pi}\widehat{b}^*_{t+1} = \widehat{y}_t + \frac{\pi - 1}{\pi}\widehat{b}^*_t - s_c\widehat{c}_t - s_i\widehat{i}_t, \tag{39}$$

$$\widehat{p}_{t+1} - \widehat{p}^*_{t+1} = \widehat{p}_t - \widehat{p}^*_t \tag{40}$$

$$\widehat{b}_t + \widehat{y}_t - s_c\widehat{c}_t - s_i\widehat{i}_t - \beta\widehat{b}_{t+1} = 0. \tag{41}$$

The remaining equations define output ($\widehat{y}_t$),the real interest rate, the real wage, and net exports[6].

$$\widehat{y}_t - s_n\widehat{l}_t - s_k\widehat{s}_t - \widehat{a}_t = 0 \tag{42}$$

$$\widehat{r}_t - \widehat{p}_t - \widehat{p}_{t+1} = 0 \tag{43}$$

$$\widehat{rw}_t = \widehat{w}_t - \widehat{p}_t \tag{44}$$

$$\widehat{y}_t - \widehat{nx}_t - s_c\widehat{c}_t - s_i\widehat{i}_t = 0 \tag{45}$$

[6]Note that for bond and net exports, the *hat* variables are a slightly different:

$$\widehat{b}_t \equiv \frac{b_t - b}{y},$$

and

$$\widehat{nx}_t \equiv \frac{nx_t - nx}{y}.$$

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Table 1: The baseline model

	Standard deviation		Std. Dev. Relative to Output		First-order Autocorrelation		Correlation with Output	
	US Data	Model	US Data	Model	US Data	Model	US Data	Model
Output	1.69	1.69	1.00	1.00	0.89	0.91	1.00	1.00
Consumption	1.28	1.66	0.76	0.99	0.92	0.90	0.81	0.80
Investment	5.03	5.47	2.98	3.24	0.92	0.90	0.81	0.76
Capital stock	0.32	0.68	0.19	0.40	0.97	0.97	-0.09	0.31
Utilization rate	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Capital services	n/a	0.68	n/a	0.40	n/a	0.97	n/a	0.31
Employment	1.44	n/a	0.85	n/a	0.90	n/a	0.82	n/a
Hours per week	0.38	0.86	0.22	0.51	0.90	0.90	0.78	0.34
Total Hours	1.69	0.86	1.00	0.51	0.88	0.90	0.89	0.34
Effort	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Effective labor	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Real wages	0.90	1.61	0.53	0.95	0.92	0.91	0.21	0.87
Net exports	0.39	1.81	0.23	1.07	0.93	0.90	-0.31	-0.26
Solow residual	1.00	1.54	0.59	0.91	0.90	0.90	0.87	0.93
Productivity	n/a	1.54	n/a	0.91	n/a	0.90	n/a	0.93

Cross-country correlations

	data			
	min	max	median	model
Output	-0.35	0.81	0.29	0.61
Consumption	-0.62	0.67	0.12	-0.37
Investment	-0.05	0.73	0.25	-0.41
Utilization rate	n/a	n/a	n/a	-0.38
Capital services	n/a	n/a	n/a	-0.36
Employment	-0.56	0.75	0.26	n/a
Hours/week	0.19	0.84	0.43	-0.34
Total labor input	n/a	n/a	n/a	-0.34
Real Wages	0.07	0.66	0.45	-0.16
Solow residual	-0.79	0.70	0.18	0.26
Productivity	n/a	n/a	n/a	0.26

Data sources: see data Appendix

Table 2: Labor hoarding model

	Standard Deviation				Std. Dev. Relative to Output				Correlation with Output			
	US Data	Case 1	Case 2	Case 3	US Data	Case 1	Case 2	Case 3	US Data	Case 1	Case 2	Case 3
Output	1.69	1.69	1.69	1.69	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Consumption	1.28	1.65	1.68	1.65	0.76	0.97	0.99	0.97	0.81	0.84	0.76	0.67
Investment	5.03	5.58	5.38	5.40	2.98	3.30	3.18	3.19	0.81	0.78	0.74	0.67
Capital	0.32	0.67	0.68	0.76	0.19	0.40	0.41	0.45	-0.09	0.31	0.32	0.39
Utilization	n/a	0.00	0.00	0.00	n/a	0.00	0.00	0.00	0.92	-0.80	0.01	-0.40
Capital Services	n/a	0.67	0.68	0.76	n/a	0.40	0.41	0.45	n/a	0.31	0.32	0.39
Employment	1.44	0.37	0.57	0.66	0.85	0.22	0.34	0.39	0.82	0.33	0.36	0.43
Hours per week	0.38	0.19	0.30	0.35	0.22	0.12	0.18	0.21	0.78	0.33	0.36	0.43
Total Hours	1.69	0.57	0.87	1.01	1.00	0.34	0.52	0.60	0.89	0.33	0.36	0.43
Effort	n/a	0.10	0.15	0.30	n/a	0.06	0.09	0.18	n/a	0.33	0.36	0.43
Effective Labor	n/a	0.66	1.02	1.31	n/a	0.39	0.61	0.78	n/a	0.33	0.36	0.43
Real Wages	0.90	1.60	1.63	1.63	0.53	0.95	0.96	0.96	0.21	0.92	0.81	0.69
Net Exports	0.39	1.75	1.87	2.03	0.23	1.03	1.10	1.20	-0.31	-0.32	-0.20	-0.08
Solow residual	1.00	1.57	1.54	1.49	0.59	0.93	0.91	0.88	0.87	0.97	0.96	0.94
Productivity	n/a	1.55	1.53	1.47	n/a	0.92	0.90	0.87	n/a	0.95	0.91	0.84

	Cross-Country Correlations			
	Data: median	Case 1	Case 2	Case 3
Output	0.29	0.53	0.66	0.65
Consumption	0.12	-0.38	-0.37	-0.36
Investment	0.25	-0.47	-0.37	-0.37
Utilization rate	n/a	-0.69	-0.89	-0.33
Capital services	n/a	-0.38	-0.36	-0.48
Employment	0.26	-0.23	-0.42	-0.55
Hours	0.43	-0.23	-0.42	-0.55
Real wages	0.45	-0.08	-0.22	-0.32
Solow residual	0.18	0.44	0.54	0.63
Productivity	n/a	0.26	0.26	0.26

Notes:
Case 1 is Bils-Cho baseline (b = 1.57; f = 2; j = 3).
Case 2 is the high hours elasticity case (b = 1.05; f = 1; j = 1).
Case 3 is the high-hours and high effort elasticities case (b = 1.05; f = 1; j = 0.14).

Table 3. Capital Utilization Model

	Standard Deviation				Std. Dev. Relative to Output				Correlation with Output			
	US Data	Case 1	Case 2	Case 3	US Data	Case 1	Case 2	Case 3	US Data	Case 1	Case 2	Case 3
Output	1.69	1.69	1.69	1.69	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Consumption	1.28	1.46	1.31	1.29	0.76	0.87	0.78	0.77	0.81	0.87	0.97	0.98
Investment	5.03	4.71	3.77	3.58	2.98	2.79	2.23	2.12	0.81	0.84	0.95	0.97
Capital	0.32	0.50	0.28	0.24	0.19	0.30	0.17	0.14	-0.09	0.21	0.08	0.06
Utilization	n/a	0.70	1.32	1.39	n/a	0.41	0.78	0.82	0.92	0.95	0.99	0.99
Capital Services	n/a	0.83	1.33	1.39	n/a	0.49	0.78	0.82	n/a	0.93	1.00	1.00
Total Hours	1.69	0.67	0.43	0.39	1.00	0.40	0.25	0.23	0.89	0.50	0.79	0.86
Real Wages	0.90	1.47	1.38	1.37	0.53	0.87	0.82	0.81	0.21	0.92	0.98	0.99
Net Exports	0.39	1.31	0.63	0.50	0.23	0.77	0.37	0.30	-0.31	-0.29	-0.42	-0.45
Solow residual	1.00	1.51	1.50	1.50	0.59	0.89	0.89	0.89	0.84	0.96	0.99	0.99
Productivity	n/a	1.24	0.96	0.92	n/a	0.73	0.57	0.55	n/a	0.95	0.98	0.99

Cross-country correlations

	Data: median	Case 1	Case 2	Case 3
Output	0.29	0.68	0.57	0.52
Consumption	0.12	-0.15	0.14	0.18
Investment	0.25	-0.19	0.04	0.07
Utilization rate	n/a	0.89	0.67	0.60
Capital services	n/a	0.44	0.63	0.57
Hours	0.43	0.05	0.84	0.93
Real wages	0.45	0.06	0.25	0.27
Solow residual	0.18	0.40	0.42	0.40
Productivity	n/a	0.26	0.26	0.26

Notes:
Case 1 is the Basu-Kimball depreciation elasticity (zeta = 1.00).
Case 2 is the King-Rebelo depreciation elasticity (zeta = 0.10).
Case 3 is the high depreciation elasticity (zeta = 0.05).

Table 4: Model with Labor Hoarding and Variable Capital Utilization

	Standard Deviation				Std. Dev. Relative to Output				Correlation with Output			
	US Data	Case 1	Case 2	Case 3	US Data	Case 1	Case 2	Case 3	US Data	Case 1	Case 2	Case 3
Output	1.69	1.69	1.69	1.69	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Consumption	1.28	1.45	1.32	1.35	0.76	0.86	0.78	0.80	0.81	0.90	0.95	0.85
Investment	5.03	4.74	3.86	4.10	2.98	2.80	2.28	2.43	0.81	0.86	0.93	0.80
Capital	0.32	0.49	0.31	0.43	0.19	0.29	0.18	0.25	-0.09	0.20	0.11	0.23
Utilization	n/a	0.70	1.31	1.36	n/a	0.41	0.78	0.81	0.92	0.95	0.98	0.96
Capital Services	n/a	0.82	1.33	1.42	n/a	0.48	0.79	0.84	n/a	0.93	1.00	0.99
Employment	1.44	0.29	0.29	0.44	0.85	0.17	0.17	0.26	0.82	0.52	0.73	0.60
Hours per week	0.38	0.15	0.15	0.23	0.22	0.09	0.09	0.14	0.78	0.52	0.73	0.60
Total Hours	1.69	0.44	0.44	0.67	1.00	0.26	0.26	0.40	0.89	0.52	0.73	0.60
Effort	n/a	0.08	0.08	0.20	n/a	0.04	0.05	0.12	n/a	0.52	0.73	0.60
Effective Labor	n/a	0.51	0.52	0.88	n/a	0.30	0.31	0.52	n/a	0.52	0.73	0.60
Real Wages	0.90	1.49	1.36	1.36	0.53	0.88	0.81	0.80	0.21	0.96	0.97	0.86
Net Exports	0.39	1.23	0.74	1.23	0.23	0.73	0.44	0.73	-0.31	-0.36	-0.35	-0.07
Solow residual	1.00	1.58	1.57	1.53	0.59	0.94	0.93	0.90	0.87	0.99	0.99	0.98
Productivity	n/a	1.26	0.95	0.92	n/a	0.74	0.56	0.55	n/a	0.97	0.97	0.86

	Cross-Country Correlations			
	Data: median	Case 1	Case 2	Case 3
Output	0.29	0.59	0.66	0.83
Consumption	0.12	-0.16	0.15	0.21
Investment	0.25	-0.26	0.07	0.04
Utilization rate	n/a	0.80	0.77	0.99
Capital services	n/a	0.40	0.71	0.80
Employment	0.26	0.23	0.64	-0.22
Hours	0.43	0.23	0.64	-0.22
Real wages	0.45	0.11	0.24	0.25
Solow residual	0.18	0.51	0.58	0.83
Productivity	n/a	0.26	0.26	0.26

Notes:
Case 1 is the Bils-Cho effort parameters combined with the Basu-Kimball depreciation elasticity.
Case 2 is the moderately elastic case (combination of case 2 from table 2 and case 2 from table 3).
Case 3 is the extremely elastic case (combination of case 3 from table 2 and case 3 from table 3).