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Working Papers

Research Department

WORKING PAPER NO. 97-27

DIAGNOSTIC EVALUATION OF THE REAL BUSINESS CYCLE MODEL WITH FACTOR HOARDING

Gwen Eudey
Visiting Economist
Federal Reserve Bank of Philadelphia

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The views expressed here are those of the author and do not necessarily represent the views of the Federal Reserve Bank of Philadelphia or the Federal Reserve System. I thank Satyajit Chatterjee, Robert Cumby, David DeJong, and Roberto Perli, and others at UC Davis, the MidWest Macro Annual, and Philadelphia Federal Reserve Bank for their comments and suggestions. All errors and omissions are my own. Comments are welcome by e-mail: gwen.eudey@phil.frb.org or by phone 215-574-6440.

ABSTRACT

This paper proposes evaluating the assumptions of the RBC model rather than merely the ability of model-constrained data to match moments of official data counterparts. Reduced-form relationships can be used to create model-consistent derivations of capital and labor input. Since several relationships exist for each input, comparison of their properties highlights weaknesses and strengths in the model assumptions. Applied to the RBC model with factor hoarding and depreciation through use, the approach highlights weaknesses in the standard utility function and casts doubt upon use of the model to improve official capital stock measures or utilization rates.

DIAGNOSTIC EVALUATION OF THE REAL BUSINESS CYCLE MODEL WITH FACTOR HOARDING

1. Introduction

The bulk of evaluation of real business cycle (RBC) models evaluation has focused on the ability of simulated or model-constrained data to mimic the statistical characteristics of official or unconstrained data counterparts. In this paper, I propose not a new method of evaluation, but rather an additional set of data that we might consider. These data are created from reduced-form relationships in the model. Rather than asking how well one series "fits" another, I examine the broad ability of the model to characterize relationships between variables in the economy. I do this by asking if the reduced-form relationships between variables implied in the model are well-approximated by the official data.

This approach is similar in spirit to earlier work (*QJE* 1985) by Mankiw, Rotemberg, and Summers, in which they examined whether the parameter estimates obtained from simultaneous estimation of the Euler equations derived from a dynamic optimization problem were economically reasonable. GMM estimation showed that the parameterizations needed to explain the relationship between consumption and leisure in the official data violated our economic intuition (either consumption or leisure would have to be an inferior good). Their procedure, however, has the shortcoming that the data were not constrained by the full general equilibrium model, but rather by the Euler equations alone. GMM estimation is now frequently used to fully calibrate the RBC model, and under this larger set of model constraints, the utility parameter estimates are more in keeping with economic theory.[1] Consequently, the fit of these relationships might be expected to be much worse under the new parameterization. What is proposed here is a fairly intuitive and non-technical means to gauge the fit of relationships between variables in the model to those in the official data but one that takes advantage of the parameterizations obtained from full GMM estimation.

Reduced-form relationships between state and control variables are highly complicated functions of the underlying parameter values in the system. It takes a keen eye to derive economic intuition from these variables in analytic form. However, substitution of economic values for these parameters yields simple numeric relationships between observable variables in the economy. For the non-linear class of RBC models, these relationships are defined in deviation (from steady state log levels) form. Expressed in deviation form, one might find, for example, that the labor supply decision is equal to a linear combination of consumption and output plus error. This numeric relationship can be used to create a *model-consistent* definition of hours worked by using official consumption and output data in combination with the parameter estimates and relationships defined by the model. Just as we evaluate a simulated (or GMM constrained) labor supply series, one can evaluate the statistical characteristics or fit of this model-consistent series relative to the actual official hours worked series.

Two methods are common for this type of series-by-series comparison. The most prevalent is to treat output as a numeraire and compare correlations between output and other series, or the relative volatility of those series, in the model and in the unconstrained data.

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[1] See, for example, Christiano and Eichenbaum (1992), Burnside, Eichenbaum, and Rebelo (1993), and Burnside and Eichenbaum (1996).

Watson (1993) proposes a more rigorous series-by-series comparison that effectively measures the goodness of fit (R-squared) of the model series to that same series in the official data. I choose in this paper to take the former approach.

Other means of evaluating model performance are related to analysis of model relationships. Rotemberg and Woodford (*AER* 1996) compare the forecasting ability of the RBC model to that of an unconstrained VAR, thereby quantifying the value-added of the model structure in identification of the business cycle. Evaluation of the reduced-form relationships as proposed here has no effect on that procedure (it affects neither the model nor the variables that enter the unconstrained VAR).

DeJong, Ingram, and Whiteman (*JBES* 1996) use Bayesian methods to back out the uncertainty about the parameterization of the model in addition to that error from model specification and measurement. Since I take the parameter values as given (through GMM), I am unable to make use of this type of goodness-of-fit measure. There is a relationship, however, between their findings and what one learns comparing GMM utility parameter estimates under full model specification with those in Mankiw, Rotemberg, and Summers: some parameter estimates more closely match their unconstrained values in the data than do others. In other words, the goodness of fit of some of the relationships in the GMM estimation is better than others.

These approaches attempt to measure how far off the model is in its ability to match moments (including parameter means) in the data. By looking at the economic relationships implied by the calibrated model we gain appreciation for how the model and parameterizations determine the failures and the successes of the theory. This information can be used diagnostically to further RBC model development.

Burnside and Eichenbaum's factor hoarding model (AER 1996) is used to demonstrate the method. Their model is chosen for two reasons. First, it performs relatively well according to at least two of the evaluation methods described above (they compare model second moments and forecasting power to those in the data), so that the factor hoarding model is now a new standard in RBC papers. Second, in their paper, Burnside and Eichenbaum use the model to define the capital input series they wish to match in the data; the procedure I recommend allows one to compare alternative model-consistent capital input series to see if they are, in turn, consistent with each other.

Burnside and Eichenbaum present a model in which capital depreciation depends on utilization, an assumption not made in the official capital stock data. Based on the assumption of their model and the reduced-form relationship for utilization, they construct a model-consistent capital stock series. This series is used in the calibration of the model and in the simultaneous derivation of work effort (there is also variable labor use) and the Solow residual. I show that the model allows us to find alternative estimates of these variables using different first-order conditions and simultaneously solving for the three series. The alternative capital stock measures have very different statistical characteristics, implying that the choice of benchmark capital series in their model evaluation is not only arbitrary but important.

Looking at alternative model-consistent capital stock measures reveals an important weakness in the variable-depreciation model: depreciation through use is entirely a theoretical construct. If one uses that theory to infer depreciation rates in the data, different relationships from the same model and same set of calibrated parameter values yield capital stock estimates with quite distinct statistical properties. There is no reason to think one more plausible than another unless one is willing to rank some relationships in the model as stronger than others.

One such weak relationship is that between labor and consumption in the utility function. The way in which this relationship seems to fail suggests incorporating greater co-movement between leisure and consumption, thus reducing the volatility of the shadow price. Unfortunately, however, this only highlights a greater weakness of the model that is brought out in Mankiw, Rotemberg, and Summers' original work: non-separability should take the form of substitution rather than complementarity, so that a rise in consumption corresponds to a fall in leisure (rise in labor). That results in positive co-movement between consumption and labor as is observed in the data, but it violates the economic intuition that neither leisure nor consumption is an inferior good.

What may be considered a positive finding from the analysis, however, is that the properties of the measured Solow residual are very robust to alternative model-consistent measures of labor and capital input. The implication is that the theory, rather than the particular properties of the inputs, defines the productivity measure when there is variable input use. This is a very nice property of the model. Variable depreciation and utilization are valuable assumptions in the model, as Burnside and Eichenbaum show in their paper. Shock propagation is extended through the effect of utilization on the future capital stock, which, in turn, affects production through two channels (future utilization and the size of the capital stock being used). Noisy productivity shocks are thus consistent with serial correlation in output.[2] In addition, the forecasting ability of the model is improved, since depreciation and therefore future production

[2] Burnside and Eichenbaum also allow for a government spending shock.

depend on current state variables. Understanding how to measure capital under this specification would therefore be an important contribution.

The rest of the paper is organized as follows. In section II Burnside and Eichenbaum's model is presented and the solution method described. Section III describes the official data. In Sections IV and V I present alternative model-consistent measures of capital and hours worked and highlight the strengths and weaknesses of those relationships by comparing them to the official data. Section VI concludes by discussing how one can use this approach as a diagnostic tool to "fix" or improve the model.

2. The model

The model follows Burnside and Eichenbaum (*AER* 1996) exactly. It is a representative agent RBC model with both government spending and technology shocks. Two non-standard assumptions set the model apart. (1) Workers choose the labor decision before they observe the government and productivity shocks; after the shocks are observed, they make optimal adjustments to their work effort, which enters into the production function in the same way labor supply does. Optimal work effort balances the benefits with costs to utility. (2) The capital stock decision is made a period in advance; once the shocks are observed, utilization of the capital stock is chosen. Again, utilization and capital enter the production function with the same weight. Utilization affects depreciation of the capital stock that enters the next period; this tradeoff determines optimal utilization.

Variable depreciation of the capital stock improves the forecasting power of the model. All other things being equal, higher output today increases depreciation of the capital stock entering the next period, resulting in a higher optimal investment allocation today. This raises the volatility of investment relative to output, as we observe in the data. It also improves the forecasting power of the model, since capital use today (a state variable) affects future productivity through this additional channel.

Capacity utilization and work effort are not observable in the data. In addition, the capital stock measure consistent with the model is one that assumes variable depreciation. That definition is not consistent with the official data. Traditional measures of the Solow residual are also inappropriate, since the inputs into production are non-standard. Burnside and Eichenbaum, therefore, use reduced-form relationships for capital, capital use, work effort, and productivity to simultaneously derive these variables. The capital and capital use relationships that they choose to use are independent of the measurement of technology. That is not the case for work effort.

The social planner's problem is to maximize utility by choosing consumption (C), the level of employment (N), the amount of work effort (W), the capital stock (K), and capital utilization (U). In this and what follows, levels of variables are represented by capital letters, log levels by lower case letters, and deviations from log steady state by a "hat."

There are two types of exogenous disturbances to the economy, both of which affect the resource constraint. The first is a labor-augmenting productivity shock that is assumed to follow a random walk with drift:

$$X_t = X_{t-1} e^{\gamma + \nu_t}$$

The second is an exogenous government spending shock that has no (direct) impact on utility:

$$G_t = X_t e^{g_t}$$

where

$$g_t = \mu(1-\rho) + \rho g_{t-1} + \varepsilon_t$$

with ε_t a noisy process.

Timing is important in the model, as the labor input decision is made at the beginning of the period *before* the government and technology shocks are realized. Although labor affects current utility and output, the input decision is made conditional on the previous period's information set. The capital stock is chosen a period ahead, so that both employment and capital are chosen conditional on the same information set. Adjustments to the intensity of use of both of these inputs can be made *after* current period shocks are realized. These adjustments take the form of variable work effort (which affects current utility) and variable capital utilization (which affects current depreciation in the resource constraint).

The social planner's problem is

$$Max \ \{ \ E_0 \sum_{t=0}^{\infty} \beta^t [\ln(C_t + \theta N_t \ln(T - \xi - W_t \ f) + \theta(1 - N_t)\ln(T)] \ \}$$

$$s.t. \quad C_t + K_{t+1} - (1 - \delta U_t^{\varphi}) \ K_t + G_t = (K_t U_t)^{1-\alpha} \ (N_t \ f \ W_t X_t)^{\alpha}$$

Durability of the capital stock in the Cobb-Douglas production function makes the first-order condition for that variable non-linear. Using a first-order Taylor expansion about the steady state, the first order condition is linearized relative to its stationary value. The linearized first-order conditions follow.

$$-\ \hat{c}_t = \hat{\lambda}_t \tag{1}$$

$$\hat{\lambda}_t = \hat{\lambda}^e_{t+1} + \mathrm{X}\ [\hat{y}^e_{t+1} - \hat{k}_{t+1}] \tag{2}$$

$$\hat{u}^e_{t+1} = \varphi^{-1}\ [\hat{y}^e_{t+1} - \hat{k}_{t+1} + \hat{x}^e_{t+1}] \tag{3}$$

$$\hat{w}_t = \frac{N\ f\ \theta}{N\ f\ \theta + \alpha\ f\ Y/C}\ [\hat{y}_t + \hat{\lambda}_t - \hat{n}_t] \tag{4}$$

$$\hat{w}^e_t = \Upsilon\ [\hat{y}^e_t + \hat{\lambda}^e_t - \hat{n}_t] \tag{5}$$

$$\hat{y}_t = \frac{(1-\alpha)\ (\varphi-1)}{\varphi-1+\alpha}\ [\hat{k}_t - \hat{x}_t] + \frac{\alpha\varphi}{\varphi-1+\alpha}\ [\hat{n}_t + \hat{w}_t] \tag{6}$$

$$\hat{y}_t = \frac{\varphi}{\varphi - 1 + \alpha}[\frac{C}{Y}\hat{c}_t + \frac{K_{t+1}}{Y}\hat{k}_{t+1} - \frac{K}{Y}[\hat{k}_t - \hat{x}_t] + \frac{G}{Y}\hat{g}_t] \quad \textbf{(7)}$$

As suggested earlier, it is often difficult to attach much economic meaning to these analytical relationships. The gamma coefficient in equation (5), for example, is an extremely complicated function of all of the model parameters. Some insights are worth noting, however. The solution is expressed in deviation form. Burnside and Eichenbaum are able to use these relationships to solve for the *level* of productivity and work effort because all lagged productivity values in equations (1) through (7) cancel. This is because current capital is deflated by last period's productivity level, and everywhere the current capital enters, the deviation of current productivity enters. The deviation of current productivity, if it is a random walk, is a deviation from the previous period (plus a constant). Thus k_t - x_t depends only on the log levels of K_t and X_t. This is not a general feature of RBC model solutions; it is peculiar to the depreciation form chosen in their model.

One issue that will materialize later when creating model-consistent measures for hours worked, the capital stock, and productivity is that it will not always be possible to derive these relationships in level form. The particular reduced-form relationships defining K and X that appear in their paper are ones that can be derived in level form. That is an advantage to using those measures, but since the model is evaluated in deviation form (stationary data), one should not be limited to considering only those relationships.

3. Data and calibration

Burnside and Eichenbaum simultaneously estimate the parameter values in equations (1) through (7) using GMM. The use of GMM is immaterial to the results in their paper; this is simply a method of calibrating the model to match long-run conditions in the data, and the parameter values are nearly identical to those using less formal calibration methods. Since I will use their exact data (described below) in my procedure, the parameter estimates are the same as in their paper.[3] The parameters that were not estimated were T(1369 hours), β ($1.03^{-.25}$), f(324.8) , and ζ (60).

The data are in 1987 prices and deflated by the male and female noninstitutional population aged 16 and over. The sample runs from 1955:1 to 1992:4 (this is the last quarter for which consistent series for consumer durables, government, and private capital stocks are available in constant cost pricing). Government spending (G) is stripped of its investment component by deriving gross investment flows from NIPA estimates of government fixed capital. Those investment flows are included in the investment measure I, as are contributions to consumer durables stocks. The imputed service flow from consumer durables is included in both consumption and total output.

4. Model-consistent estimates of the capital stock

The identity for the evolution of the capital stock (implied in the resource constraint above) is

$$K_{t+1}^{mc} = (1 - \delta U_t^{\varphi})\ K_t^{mc} + I_t$$

where mc stands for "model consistent." The first- order condition with respect to utilization (Equation (3) expressed in levels) is

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[3] I thank Craig Burnside for making these data available to me.

$$U_t^{\varphi} = (1-\alpha)\ (\delta\varphi)^{-1}\ \frac{y_t}{K_t^{mc}}$$

Substituting and using the parameter values from Burnside and Eichenbaum yields their model-consistent relationship for deriving the capital stock. This can be expressed in deviation form as

$$\hat{k}_{t+1} = .99\ \hat{k}_t - .21\ \hat{y}_t + .99\ \hat{i}_t \qquad \textbf{k1}$$

Derivation of a second measure of the capital stock (k2) is more involved. Equations (6), (2), and (3) yield

$$\begin{aligned} \hat{w}^e_{t+1} = {} & \frac{\varphi-1+\alpha}{\alpha\varphi}\ \mathrm{X}^{-1}\ [\hat{\lambda}_t - \hat{\lambda}^e_{t+1}] \\ & - \frac{(1-\alpha)(\varphi-1) - (\varphi-1+\alpha)}{\alpha\varphi}\ \hat{k}_{t+1} - \hat{n}_{t+1} \end{aligned} \qquad \textbf{(A)}$$

Equations (6) and (4) imply

$$\hat{w}^e_{t+1} = \omega\ [\frac{\alpha\varphi-\varphi+1-\alpha}{\varphi-1+\alpha}\ \hat{n}_{t+1} + \hat{\lambda}^e_{t+1} + \frac{(1-\alpha)\ (\varphi-1)}{\varphi-1+\alpha}\ \hat{k}_{t+1}\ ] \qquad \textbf{(B)}$$

(A), (B) and (5) are used to derive what will be key relationships in this and the following section:

$$\hat{n}_{t+1} = 5.0987044\hat{\lambda}_t - 2.101803\hat{k}_{t+1} \quad \textbf{(8)}$$

$$\hat{\lambda}^e_{t+1} = .7703019 \ \hat{\lambda}_t + .114142 \ \hat{k}_{t+1} \quad \textbf{(9)}$$

Using these relationships to get future values of labor, expected shadow prices, and expected work effort, in terms of state variables, (A) becomes

$$\hat{k}_{t+1} = 1.6539867 \ \hat{\lambda}_t \quad \textbf{(10)}$$

Using (1) to substitute for shadow prices yields

$$\hat{k}_{t+1} = -1.6539867 \ \hat{c}_t \quad \textbf{k2}$$

Another relationship between the capital stock and observable data is evident in equation (8). Substituting for the shadow price we have a relationship between the stock of capital chosen today and the labor input chosen tomorrow. k3 is a forward-looking relationship, but both the capital stock and labor input decisions are made conditional on the same information set, so that they depend only on variables observable at time t.

$$\hat{k}_{t+1} = \frac{-1}{2.101803} \left(\hat{n}_{t+1} + 5.0987044 \ \hat{c}_t\right) \quad \textbf{k3}$$

Figure 1a plots the three capital stock measures with the official National Income and Product Accounts measure and Figure 1b plots the Solow residuals. k1 is estimated independently of the productivity estimate. k2 and SRk2 (the productivity measure created using k2) were derived simultaneously and are consistent with one another. For k3, simultaneous estimation of the productivity measure in levels created an exploding series, and so k3 was not used to create a new Solow residual in level form; Burnside and Eichenbaum's measure of productivity was chosen to convert the deviation-from-steady-state variable into log levels. Note that SRk2 and k2 are consistent with a much greater increase in productivity (rather than capital inputs) throughout the 1980s than is implied by the other measures.

Table 1 provides further descriptive statistics of the alternative capital stock series implied by the model. The low correlation with the official data is not bad--the model hypothesizes that these series will behave differently. The correlation between Burnside and Eichenbaum's chosen capital stock measure and the other model-consistent derivations of the capital stock is, however, disturbing, as is the high volatility of both k2 and k3. This high volatility results from the implied relationship between the costate variable and consumption. Interestingly, despite large differences between capital stock measures, each of the implied Solow residuals behaves very much like the other. Although evaluating alternative relationships for capital defined by the first- order conditions revealed some weaknesses in the model, it has also revealed a strength with regard to the productivity measure. The supply-side source of dynamics to the system is not as sensitive to the capital stock measure used. The primary determinant of the productivity measure is the assumed form of the production function (propagation extended through variable depreciation) rather than the data.

5. Model-consistent estimates of employment

Now that the methodology has been established, it is straightforward to establish relationships between hours worked and other observable variables. Rearranging k3, we have

$$\hat{n}_t = -5.0987044\ \hat{c}_{t-1} - 2.101803\ \hat{k}_t \qquad \textbf{n1}$$

where k1 is used as the capital input.[4]

Equations (8) and (10) in turn imply a relationship between labor and capital alone:

$$\hat{n}_t = .9808727\ \hat{k}_t \qquad \textbf{n2}$$

n1 cannot be measured jointly with the Solow residual in level form (the productivity measure was nonsensical in levels); therefore, the plot for n1 in Figure 2 uses the Burnside and Eichenbaum productivity measure to transform the deviation-form variables into levels. In deviation form, both the productivity measure and labor were simultaneously estimated. n1 is negatively correlated with the official series, but n2 performs fairly well. Looking at Table 2, one can compare these relative volatilities to those reported in Burnside and Eichenbaum for hours worked as constrained by the GMM system; in that case, the relative volatility of hours worked was .8, closely matching that of the data but neither of the model-consistent measures.

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[4] The choice of capital measure is somewhat arbitrary. The same capital input should be used in all of the alternative hours worked measures. Use of k1 eases comparisons with Burnside and Eichenbaum's results, which use that measure.

The productivity measures derived using n1 and n2 are highly correlated with output. This is good in the sense that high correlation of these variables is a general feature of the RBC model. It does seem puzzling, however, that the Solow residual should be so little affected by substituting a labor input series that is not even positively correlated with the official data. This again reveals the heavy weight of the specification of variable input-use in the derivation of the production function. The model, rather than the data, is playing a heavy hand in determining the process for productivity.

6. Discussion

In the previous two sections we examined whether we can use reduced-form relationships from the model to create measures of the capital and labor input with simple statistical properties resembling those of the official capital and hours worked data. The short answer seems to be: No. Nor do different model-consistent relationships behave like each other. There is more to be learned, however, from Tables 1 and 2 than that.

We have seen that the properties of the productivity measure are not sensitive to the type of data used for hours worked or capital. This is not to say that the level of productivity is unaffected; in some cases the level measure that was constructed simultaneously with the capital or labor measure was explosive. The GMM estimation constrained the growth rate of productivity to equal that of output, but although all first-order conditions in the model were represented in the calibration through GMM, recreating productivity using those relationships as in sections IV and V violated the balanced growth condition in some cases. The cases in which that condition was violated were those in which the full model was not used to derive the model-consistent input (i.e., k2 and n1). When all the first-order conditions are used, as they were in the

GMM estimation, the productivity and individual input series are reasonable and consistent with one another. When only a subset of the first-order conditions are used, things fall apart.

This is consistent with the insight one might glean from comparing Mankiw, Rotemberg, and Summers (1985) parameterization of the utility function to that obtained under the same GMM procedure with the full model. Since GMM estimation is not simply a matter of lining up first-order conditions, one cannot evaluate the fit of each relationship in the system in any direct way. The method used in this paper can be thought of as indirectly making such an evaluation.

One weak relationship in the model is clearly that between the arguments of the utility function and the costate variable. Both n1 and k2, which perform particularly badly, are strongly determined by that relationship. Casual examination of equations (8) and (1) reveals the source of the problem: Consumption in this reduced-form relationship co-varies negatively with hours worked. This, of course, is not observed in the data (the correlation in growth rates is approximately 35%). Introducing non-separability in utility would reduce the volatility of n1 and k2, but the type of non-separability needed to generate positive co-movement in labor and consumption violates economic intuition; either consumption or leisure would have to be an inferior good. This is exactly the finding in Mankiw, Rotemberg, and Summers; they found that, if we allowed for non-separability, the coefficients on consumption and leisure were opposite in sign.

Recent models of home production give us a new understanding of that elasticity estimate and suggest modification of the utility function in this model that might allow us to more closely match behavioral relationships in the data. At the same time, we would want to preserve the form for production. The structure of the production function is clearly an important contribution of the Burnside and Eichenbaum model; it is also not sensitive to alterations in the utility function. If we think of this evaluation as a constructive, diagnostic evaluation of the factor hoarding model, the results are suggestive of a merger of the two specifications.

Table 1
Alternative measures of the Capital Stock and Implications for the Solow Residual

I. Growth rates
A. Co-movements and volatilities of the Capital Stock measures

1.contemporaneous correlation

	official	k1	k2	k3
official	1.00			
k1	0.36	1.00		
k2	0.42	-0.52	1.00	
k3	-0.35	-0.23	-0.03	1.00

2. standard deviations (relative to output)

official	k1	k2	k3
0.22	0.11	32.22	0.44

B. Implied Solow Residual for each Capital Stock measure

1.contemporaneous correlation with output

official	k1	k2	k3
0.84	0.88	0.01	0.83

2. standard deviations (relative to output)

official	k1	k2	k3
0.89	0.89	8.89	1.11

II. HP filtered data
A. Co-movements and volatilities of the Capital Stock measures

1.contemporaneous correlation

	official	k1	k2	k3
official	1			
k1	0.85	1		
k2	-0.49	-0.33	1	
k3	-0.49	-0.37	0.91	1

2. standard deviations (relative to output)

official	k1	k2	k3
0.27	0.20	0.87	0.67

B. Implied Solow Residual for each Capital Stock measure

1.contemporaneous correlation with output

official	k1	k2	k3
0.79	0.87	0.80	0.82

2. standard deviations (relative to output)

official	k1	k2	k3
0.67	0.67	0.80	0.73

Table 2
Alternative measures of Hours Worked and Implications for the Solow Residual

I. Growth rates

A. Co-movements and volatilities of the Hours Worked measures

1.contemporaneous correlation

	official	n1	n2
official	1.00		
n1	-0.40	1.00	
n2	0.24	-0.22	1.00

2. standard deviations (relative to output)

official	n1	n2
0.78	2.56	0.11

B. Implied Solow Residual for each Hours Worked measure

1.contemporaneous correlation with output

official	n1	n2
0.84	0.68	0.99

2. standard deviations (relative to output)

official	n1	n2
1.22	3.89	1.33

II. HP filtered data

A. Co-movements and volatilities of the Hours Worked measures

1.contemporaneous correlation

	official	n1	n2
official	1		
n1	-0.8	1	
n2	27	-0.46	1

2. standard deviations (relative to output)

official	n1	n2
0.93	2.87	0.20

B. Implied Solow Residual for each Hours Worked measure

1.contemporaneous correlation with output

official	n1	n2
0.89	0.88	0.98

2. standard deviations (relative to output)

official	n1	n2
0.67	4.27	1.33

Figure 1a

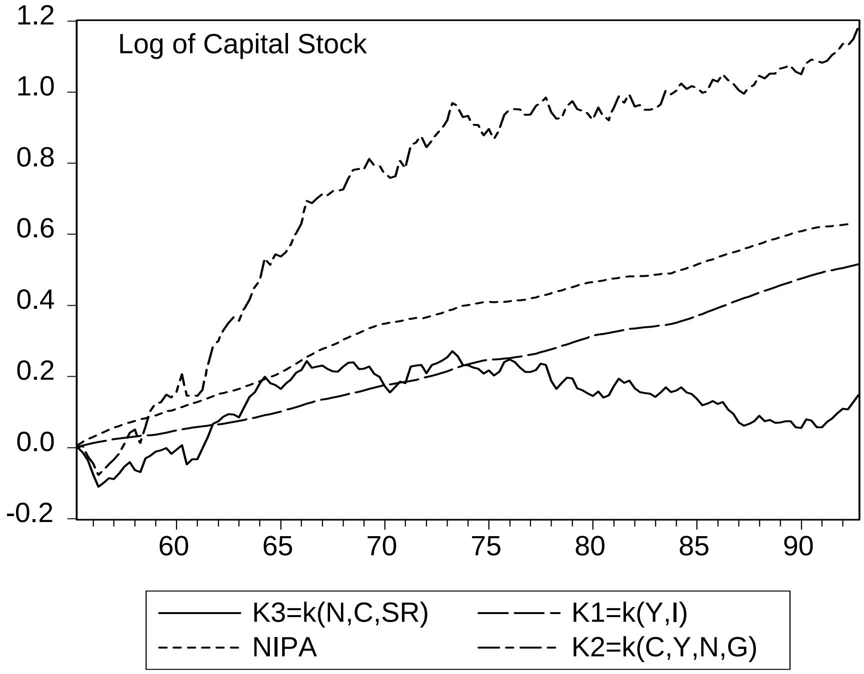


Figure 1b

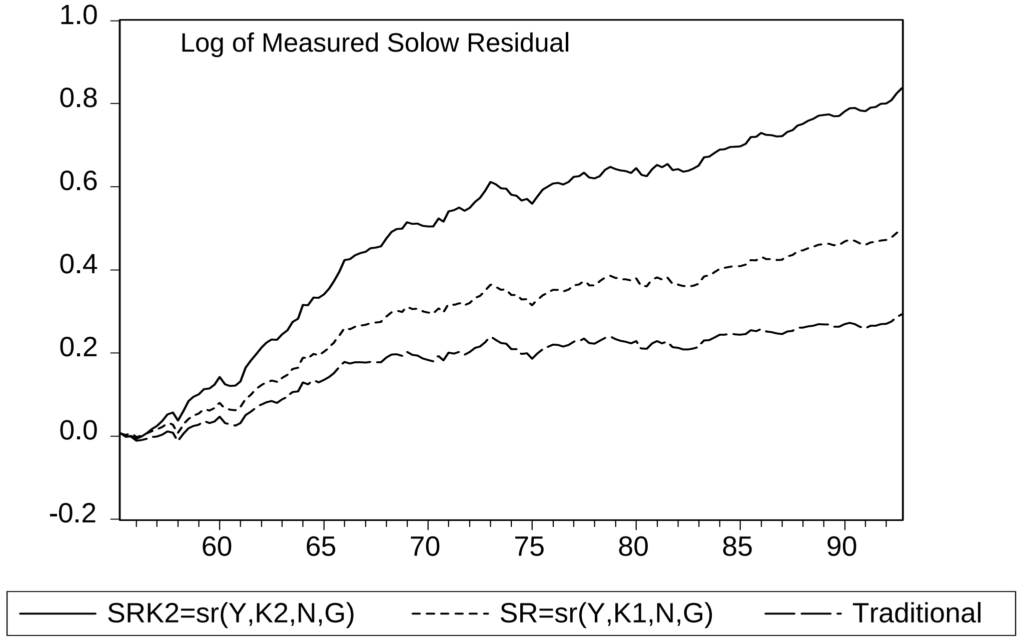


Figure 2a

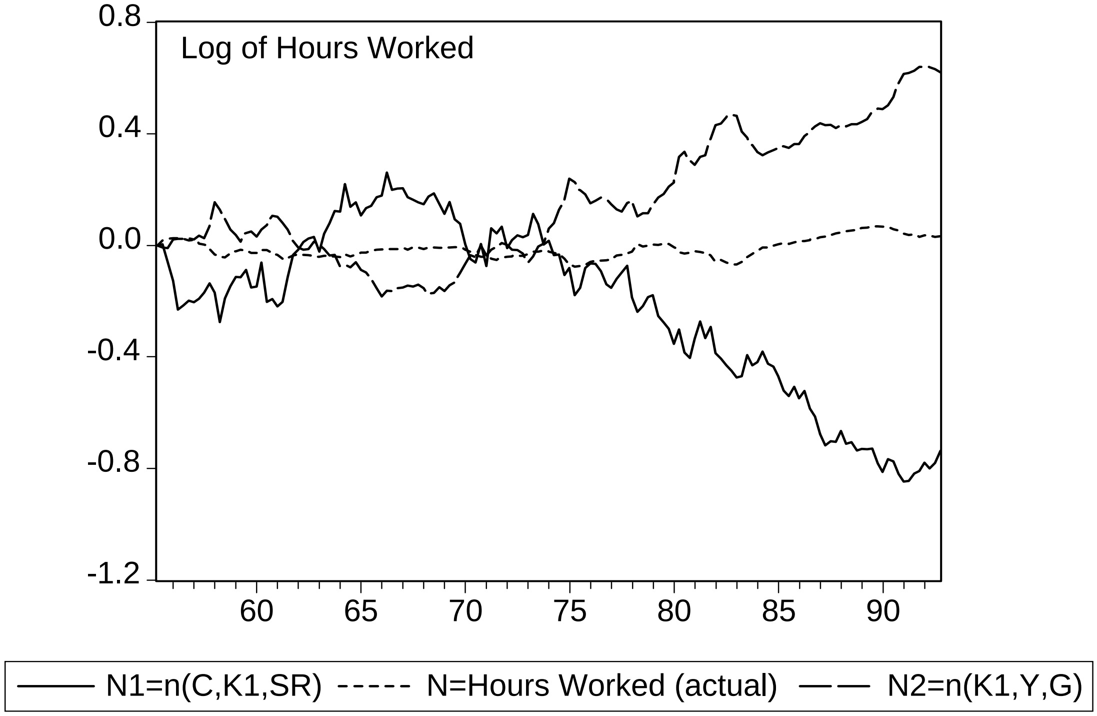
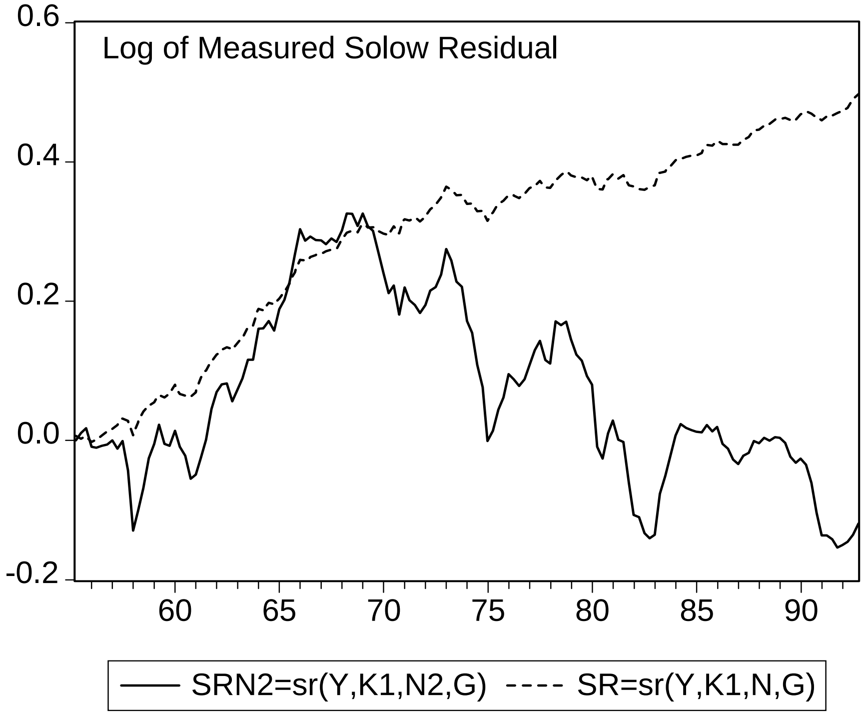


Figure 2b



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