Did Technology Shocks Cause
the 1990–91 Recession?

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I. Introduction

Real business cycle theory has been used to determine the statistical properties of aggregate fluctuations induced by technology shocks. The finding is that technology shocks have been an important contributor to fluctuations in the U.S. economy. For example, Kydland and Prescott (1991) estimate that if the only impulses were technology shocks, the U.S. economy would have been 70 percent as volatile as it has been over the postwar period. In this paper we employ the theory to answer the question, "Did technology shocks cause the 1990–91 recession?"

Answering this question requires the determination of the effects of technology shocks on the *path* of the economy. The procedure that we use to make this determination is as follows. First, we construct a model economy and calibrate it so that its steady-state matches actual 1987 values. Data for other years are used to determine the realizations of the shocks and the nature of the stochastic processes generating these shocks. Given these stochastic processes, the equilibrium decision rules for our calibrated economy are computed. We then construct the path for the economy implied by the model for the period 1984:1 to 1992:3. We set 1984:1 model values of the state variables equal to actual 1984:1 values and use the decision rules and the *realized* shocks to construct this path. Finally, we examine whether the model economy experiences a recession in 1991 as did the U.S. economy.

Business cycles are variations in output per adult that are in large part accounted for by variation in the per adult time allocated to market production. Figure 1 plots the time path of the per adult labor input. During the 1983:1–1989:1 period there was a remarkable twelve percent increase in the labor input per adult. Beginning in 1990:2 there has been a decline of nearly 6 percent in this per adult labor input. An unusual feature of the recovery subsequent to the 1990–91 recession is that this labor input variable has continued to decline well into the recovery. This unusual behavior leads to a related question, "Did technology shocks cause the slow recovery?"

FIGURE 1
HOURS WORKED PER ADULT
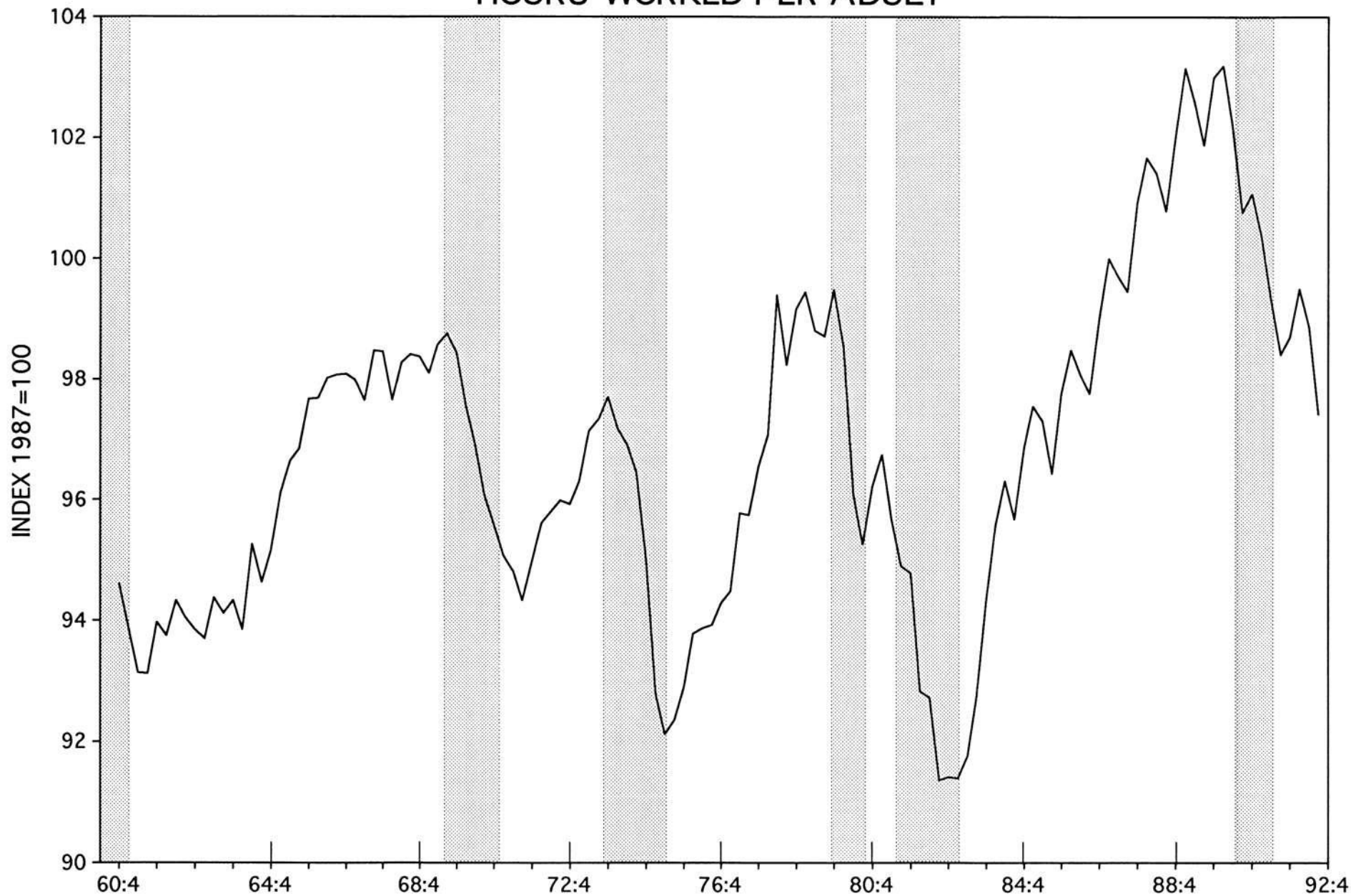
Note: Plotted is the Citibase measure of the seasonally adjusted total hours at work in all industries (LHOURS) divided by the civilian noninstitutional population aged twenty and over. The jaggedness beginning in 1984 indicates a problem with the seasonal adjustment procedure used by Citibase.

We found it necessary to modify the standard real business cycle model in four ways in order to answer the posed question. First, given the enormous changes in the relative prices of durables as depicted in Figure 2, we could not treat technology change as being neutral with respect to different types of final goods. Following Long and Plosser (1983) and Greenwood, Hercowitz, and Krusell (1992) we consider multiple production sectors with technology change differing across sectors. Second, we assume that there is a technology employed within the household sector which produces a consumption flow from the stock of consumer durables. Third, we consider land to be a factor of production in addition to labor and capital. Our fourth modification is to introduce population growth.

II. What Are These Technology Shocks?

By definition, technology shocks are changes in the production functions, or more generally the production possibility sets, of the profit centers. In a growing economy we observe positive technology change over time with these production possibilities sets shifting out as production processes are improved or new ones invented. One factor leading to this change is growth of public scientific and technical knowledge. This knowledge can, in principle, be accessed and used by firms in any country to develop a new technology and to improve upon an existing one. Thus, this factor does not account for the differences in the relative per capita wealth of nations at a point in time. The reason why India has a per capita income only one-twentieth the U.S. value can not be because India is in some other world with a much smaller stock of technical knowledge.

Similarly, changes in this stock of knowledge cannot account for the business cycles observed within a country over time. Although the rate at which inventions and discoveries are made may vary over time, the stock of knowledge should not decrease. Thus, these variations are not likely

FIGURE 2
PRICES OF INVESTMENT GOODS RELATIVE TO CONSUMPTION

CONSUMER DURABLES

BUSINESS INVESTMENT

INDEX 1987=100
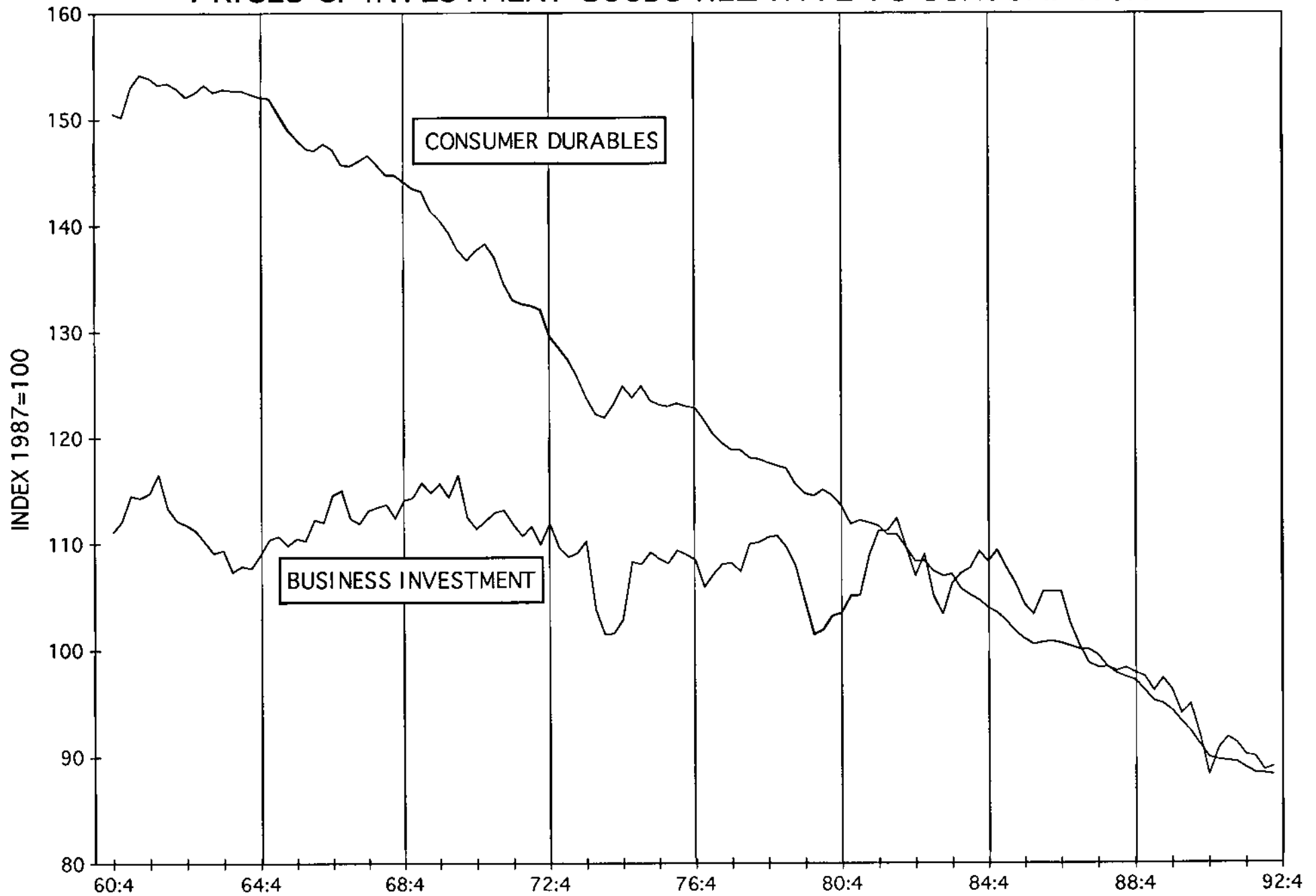
to account for the negative growth rates sometimes observed. If technology shocks are shown to cause the 1991 recession, and it is not changes in knowledge that is responsible, what is it?

Every nation has a set of rules and regulations that govern the conduct of business. These have consequences for the incentives to adopt more advanced technologies and for the resources required to operate an existing one. Bureaucracies which assist in the adoption of new technologies, say by making available technical information to businesses, foster technological growth. Systems which divert entrepreneurial talent from improving technologies to rent seeking activities have an adverse effect on growth. The reason for the huge difference between the U.S. and India must be that India has been less successful than the U.S. in setting up economic institutions conducive to development. It would not be surprising then, that changes in the legal and regulatory system within a country often induces negative as well as positive changes in technology.

A related source of technology shocks originates from the fact that we can only measure outputs and inputs which are actually traded in markets and have associated prices. In part, the set of traded factors of production and commodities are also dependent upon the economic institutions in place. For example, if the legal system is such that there is a market for pollution rights then these rights become a measured factor of production. There is a rental price of these rights like there is a rental price of land. If the government purchases some of these rights in order to reduce the amount of pollution produced, there is no technology change but simply a reduction in the endowment of a particular factor of production. If, on the other hand, pollution rights are not traded and the government imposes constraints on firms with regard to the amount of pollution per unit output, this represents a technology shock since the amount of output that can be produced from given quantities of market inputs changes.

An important consequence of our interpretation of these technology shocks is that, although they are exogenous to the profit centers, they are not exogenous to the society as a whole. If

technology shocks are an important contributor to business cycles, then changes in the political system and the institutions created by it are also important.

III. The Model Economy

The model economy employed is a three sector stochastic growth model consisting of a consumption good sector producing consumer services, nondurables, and government consumption; a consumer durables sector; and a producer durables sector. The technologies associated with each sector are as follows:

$$(3.1) \quad C_t \leq Z_t K_{1t}^{\theta_1} h_{1t}^{\theta_2} L_{1t}^{1-\theta_1-\theta_2}$$

$$X_{dt} \leq Z_{dt} Z_t K_{2t}^{\theta_1} h_{2t}^{\theta_2} L_{2t}^{1-\theta_1-\theta_2}$$

$$X_{kt} \leq Z_{kt} Z_t K_{3t}^{\theta_1} h_{3t}^{\theta_2} L_{3t}^{1-\theta_1-\theta_2},$$

where all variables are per capita values. K_{it}, h_{it}, and L_{it} are the stock of capital, hours worked, and land employed in sector i in period t and C_t, X_{dt}, and X_{kt} are consumption, investment in consumer durables and investment in productive capital, respectively. The variable Z_t is the consumption sector technology shock while Z_{dt} and Z_{kt} are the investment goods sector technology shocks relative to the consumption good sector shock. The inverses of Z_d and Z_k are the equilibrium relative prices of consumer durables and capital in terms of consumption.

Define K_t to be $\Sigma_i K_{it}$ and h_t to be $\Sigma_i h_{it}$. In addition, the total stock of land is fixed and set equal to one, so $\Sigma_i L_{it} = 1$. The stocks of durables evolve according to the following laws of motion,

$$(3.2) \quad N_{t+1} D_{t+1} = N_t[(1-\delta_d)D_t + X_{dt}]$$

$$N_{t+1} K_{t+1} = N_t[(1-\delta)K_t + X_{kt}],$$

where N_t is the population in time t.

The technology shocks Z, Z_d, and Z_k, are modeled as follows:

(3.3) $Z_t = \lambda^t z_t$, $Z_{dt} = \lambda_d^t z_{dt}$, $Z_{kt} = \lambda_k^t z_{kt}$

where

$$\log z_{t+1} = (1-\rho)\log \bar{z} + \rho\log z_t + \epsilon_{t+1}$$

$$\log z_{d,t+1} = \rho_d\log z_{dt} + \epsilon_{d,t+1}$$

$$\log z_{k,t+1} = \rho_k\log z_{kt} + \epsilon_{k,t+1},$$

where ρ, ρ_d, and ρ_k are each greater than zero but less than or equal to one; ϵ, ϵ_d, and ϵ_k are iid random variables with zero mean; and λ, λ_d, and λ_k are each greater than or equal to one.

Optimality implies that the value marginal product of each input will be equalized across sectors. Given that identical Cobb-Douglas production functions are assumed, this implies that there exist fractions, ϕ_{1t}, ϕ_{2t}, and ϕ_{3t}, where $\Sigma_i\phi_{it} = 1$, such that $K_{it} = \phi_{it}K_t$, $h_{it} = \phi_{it}h_t$, and $L_{it} = \phi_{it}$ for each i. Using this result, it is possible to aggregate over sectors to obtain the resource constraint,

(3.4) $C_t + \dfrac{X_{dt}}{Z_{dt}} + \dfrac{X_{kt}}{Z_{kt}} \leq Z_t K_t^{\theta_1} h_t^{\theta_2}.$

The population consists of a continuum of identical households of measure N_t that grows at the rate $\eta - 1$. The utility of a household in period t is given by

(3.5) $u(C_t,D_t,h_t) = \sigma\log C_t + (1-\sigma)\log D_t - \alpha h_t,$

where the second term reflects the utility from the service flow provided by the stock of durables. The fact that utility is linear in hours worked results from assuming that labor is indivisible (households can work some $\hat{h}$ hours or not at all), and that labor is allocated through a market for employment lotteries as in Rogerson (1988) and Hansen (1985).

Since there are no distortions in this economy, an equilibrium can be computed by solving a social planning problem where the objective function of the social planner is $E\{\Sigma_t \beta^t N_t U(C_t, D_t, h_t)\}$. The numerical methods we use to solve this problem, which are described in detail in Hansen and Prescott (1992), require that there be no secular trends in the variables. Therefore, we transform the model as follows: let $c_t = C_t/\gamma^t$, $x_{dt} = X_{dt}/(\gamma\lambda_d)^t$, $x_{kt} = X_{kt}/(\gamma\lambda_k)^t$, $d_t = D_t/(\gamma\lambda_d)^t$, and $k_t = K_t/(\gamma\lambda_k)^t$, where $\gamma = [\lambda\lambda_k^{\theta_1}]^{1/1-\theta_1}$. After this transformation the social planning problem can be represented by the following stationary dynamic program,

$$(3.7) \quad v(z, z_d, z_k, d, k) = \max\{\sigma\log c + (1-\sigma)\log d - \alpha h + E\{\beta\eta v(z', z_d', z_k', d', k')\}\}$$

subject to

$$c + \frac{x_d}{z_d} + \frac{x_k}{z_k} = zk^{\theta_1}h^{\theta_2}$$

$$\eta\gamma\lambda_d d' = (1-\delta_d)d + x_d$$

$$\eta\gamma\lambda_k k' = (1-\delta_k)k + x_k$$

and (3.3).

IV. Model Calibration

The parameters of the model that need to be assigned values include parameters describing the exogenous shock processes $(\bar{z}, \rho, \rho_d, \rho_k, \lambda, \lambda_d, \lambda_k)$, factor income shares (θ_1, θ_2), rates of depreciation for durables (δ_d, δ_k), and parameters describing preferences (β, σ, α). The quarterly growth rate of population, η, is taken to be 1.0032. For the most part, parameters are assigned so that the steady state of the model corresponds to actual data for the first quarter of 1987 (1987:1).

The parameters of the shock processes are obtained by examining the empirical counterparts to Z, Z_d, and Z_k. The variables Z_d and Z_k are equal to the inverses of the relative prices of

consumer durables and capital investment shown in Figure 2. Estimates of the linear trends in the logs of these variables from 75:1 to 92:3 provided values for λ_d and λ_k equal to 1.0051 and 1.0026, respectively. In addition, examination of these series lead us to choose values for ρ_d and ρ_k equal to one.

Equation (3.4) is used to obtain an empirical counterpart to the realized technology shocks, Z_t. To compute Z, however, an empirical counterpart to C, X_d, X_k, h and K are needed as well as values for the parameters θ_1 and θ_2. The first three variables are taken from the national income and product accounts. The variable C is consumption of nondurables and services plus government consumption, X_d is expenditures on consumer durables, and X_k is the difference between GNP and the first two components. Each of these components is measured in 1987 dollars and is divided by N_t, which is taken to be the population aged 20 and over. The labor input is weekly hours at work per adult scaled so that h_t is equal to its steady state value in the first quarter of 1987.[1] The steady state value used is 0.305, implying that just over 30 percent of a household's substitutable time is spent engaged in market activities. The capital series is constructed by setting $N_t K_t$ (t = 1959:1) equal to the stock of fixed private capital taken from the Musgrave (1992) for the end of 1958 and iterating forward using equation (3.2) and the empirical series X_k. The depreciation rate δ_k was chosen so that the capital stock for t = 1987:1 matches the number for 1986 as reported by Musgrave (1992). A similar procedure was used to calibrate δ_d. Figure 3 plots the realized consumption sector technology shocks path.

The parameter θ_2, which is labor's share of income, was set equal to .69 using national income data for 1987:1, which we take to be the steady state.[2] Given the stock of land, stock of fixed private capital and GNP for 1987:1, and assuming that land does not depreciate, we can obtain a value for the real interest rate (for the consumption good) from the following equation which holds in the steady state for our model:[3]

FIGURE 3
CONSUMPTION SECTOR TECHNOLOGY PARAMETERS (Z)
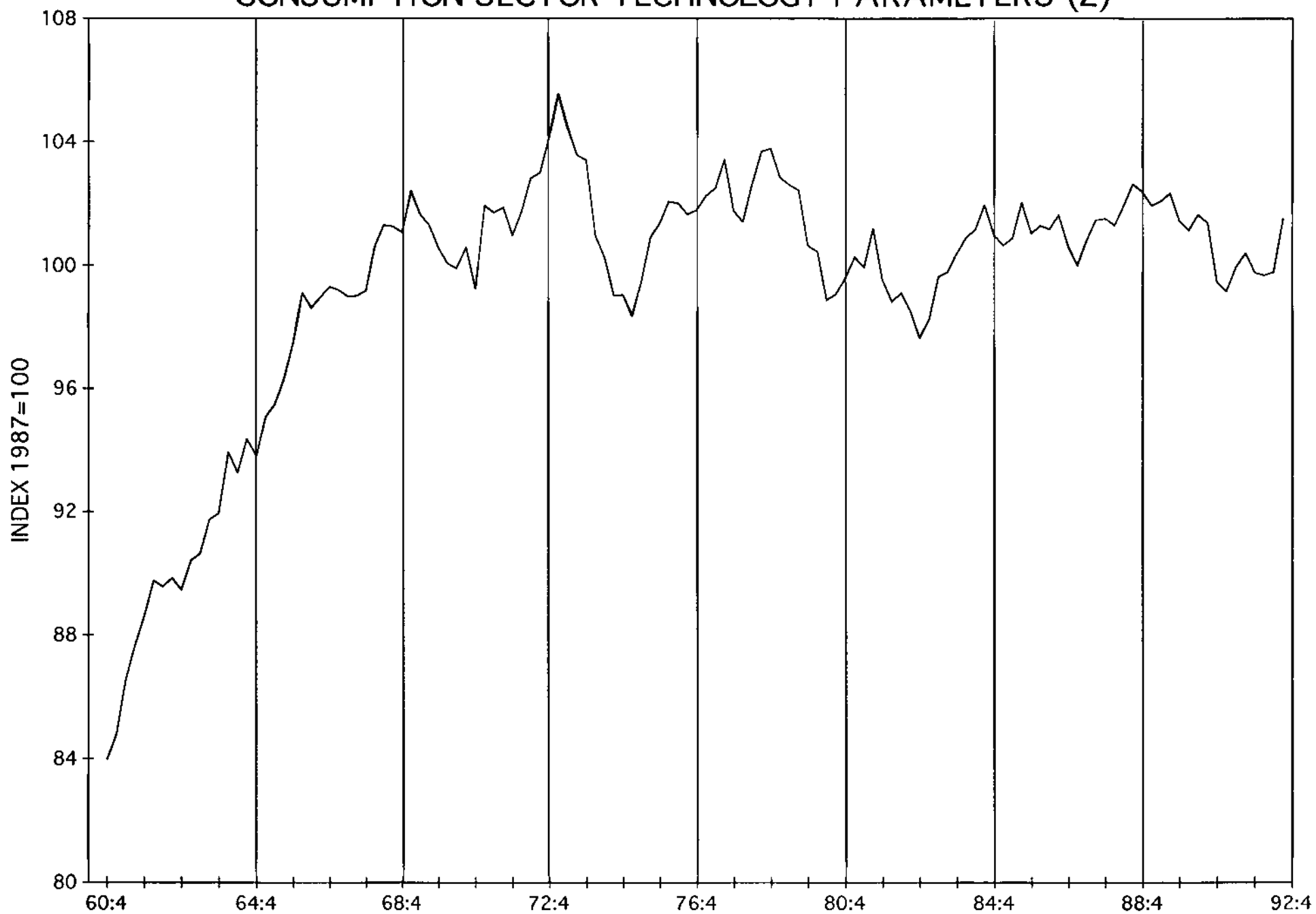
$$((1+r)/\gamma - 1)L + ((1+r)\lambda_k - 1 + \delta_k)K = (1-\theta_2)GNP.$$

Given this value for r, we set $\theta_l = ((1+r)\lambda_k - 1+\delta_k)K/GNP = .26$.

Using these values, we are able to construct a time series for Z_t. Examining this series lead us to set $\lambda = 1$ and $\rho = 0.95$. The parameter $\bar{z}$ was chosen so that the realized value of z_t is equal its value in 1987:1.

Finally, the parameters of preferences, α, β and σ, were chosen in a manner similar θ_2: the parameters were calibrated so that steady state conditions are satisfied using 1987:1 observations as steady state values.[4]

V. Findings

Figure 4 contains a plot of quarterly GNP in 1987 prices for the model economy given the realizations of the shocks for the U.S. economy from 1984:1 to 1992:3 and the expected value of the shocks from 1992:4 to 1993:4. Also plotted is the actual path of U.S. GNP through 1992:3. The key finding is that the model economy had a recession in the 1990–91 period. Not only does the timing of the recessions match, but the amplitude and duration of the downturns match as well. The second finding is that technology shocks did not cause the slow recovery.

There are some differences between the behavior of the model economy and the behavior of the U.S. economy during this period. One difference is that the model economy reacts more strongly to productivity shocks with adjustments being more rapid. As a result, the path of GNP for the model is more jagged and fluctuates about the path for the U.S. economy. This was expected given the nature of the abstraction that we employed. Model economies with some cost of people moving between sectors, time-to-build and time-to-train, and more curvature on the utility function would have resulted in slower responses (see Kydland and Prescott 1991).

FIGURE 4
GNP

INDEX 1984:1 = 100
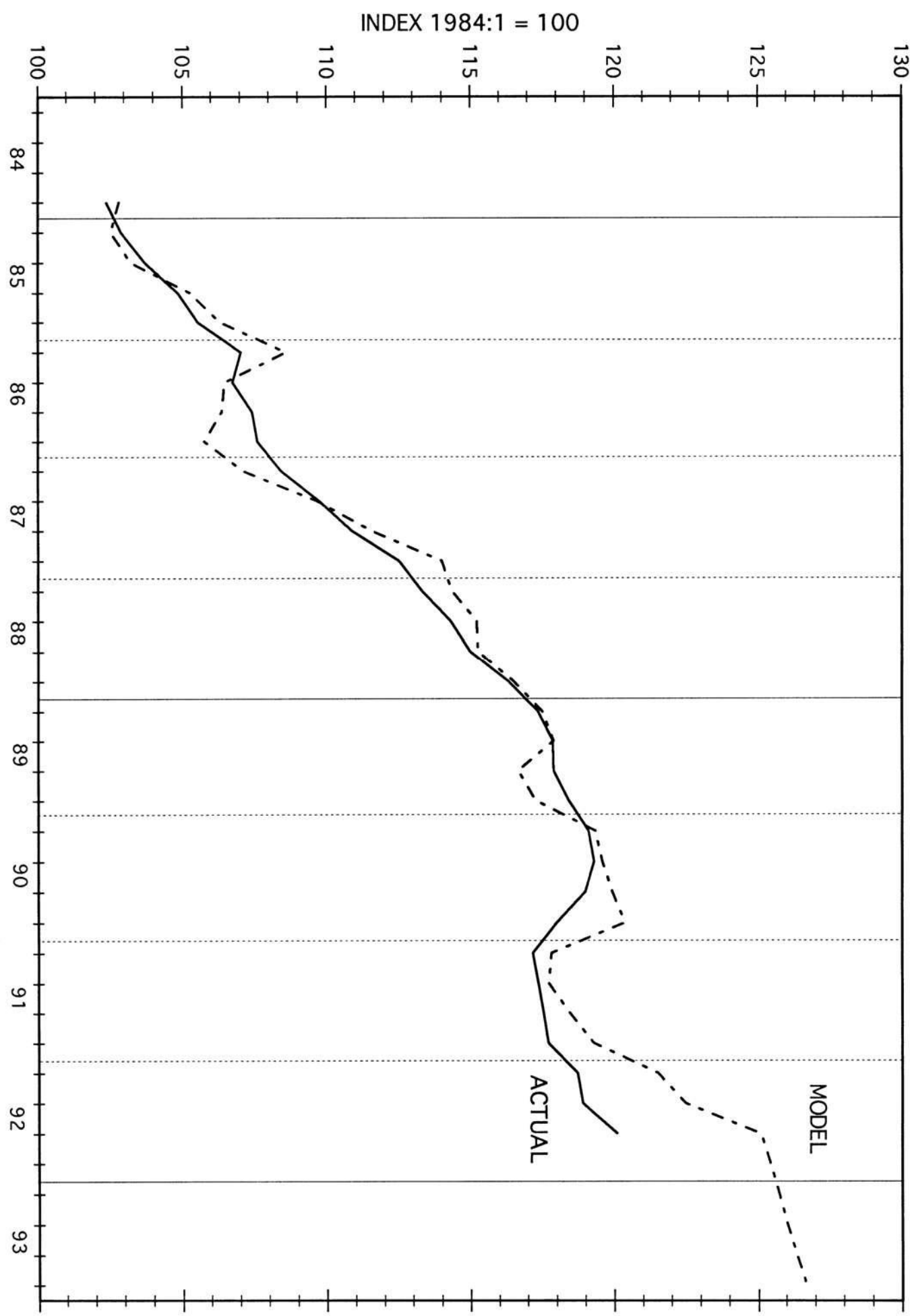
The paths of labor productivity are similar for the two economies as shown in Figure 5. Actual labor productivity was higher than that of the model in the early part of the period and grows more rapidly in 1991 and 1992. The reason for this can be seen in Figure 6 which plots the paths of the labor input per adult for the two economies. In the early period the labor input increased more rapidly in the actual economy than it did in the model. In the model hours worked per adult increase in the 1991:2–1992:3 period while in the actual economy they continued to decline. Another difference in the behavior of the model and actual economy is the behavior of business investment share. As can be seen in Figure 7, business investment as a share of GNP is higher in the model economy except in the early part of the sample.
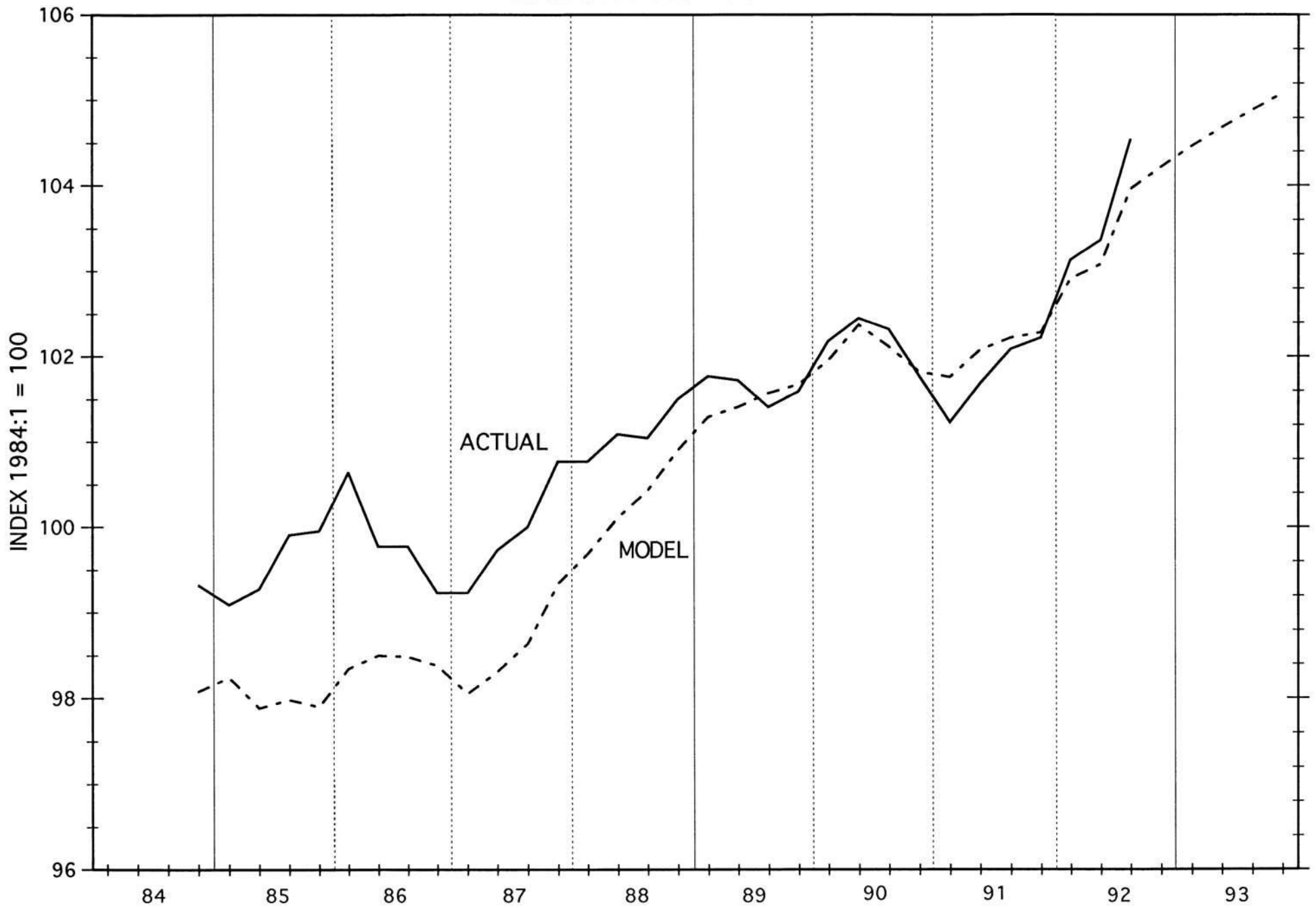
FIGURE 5
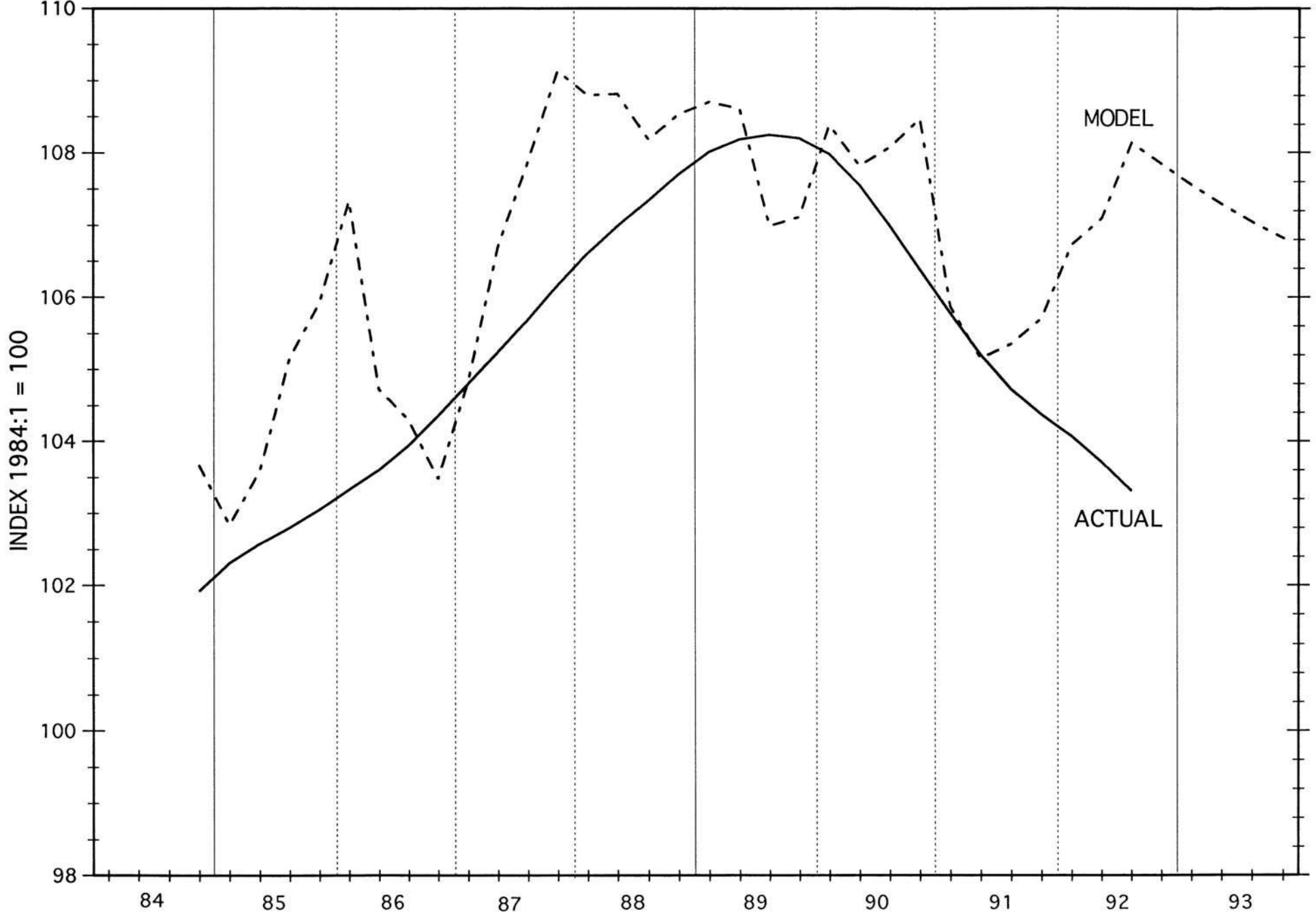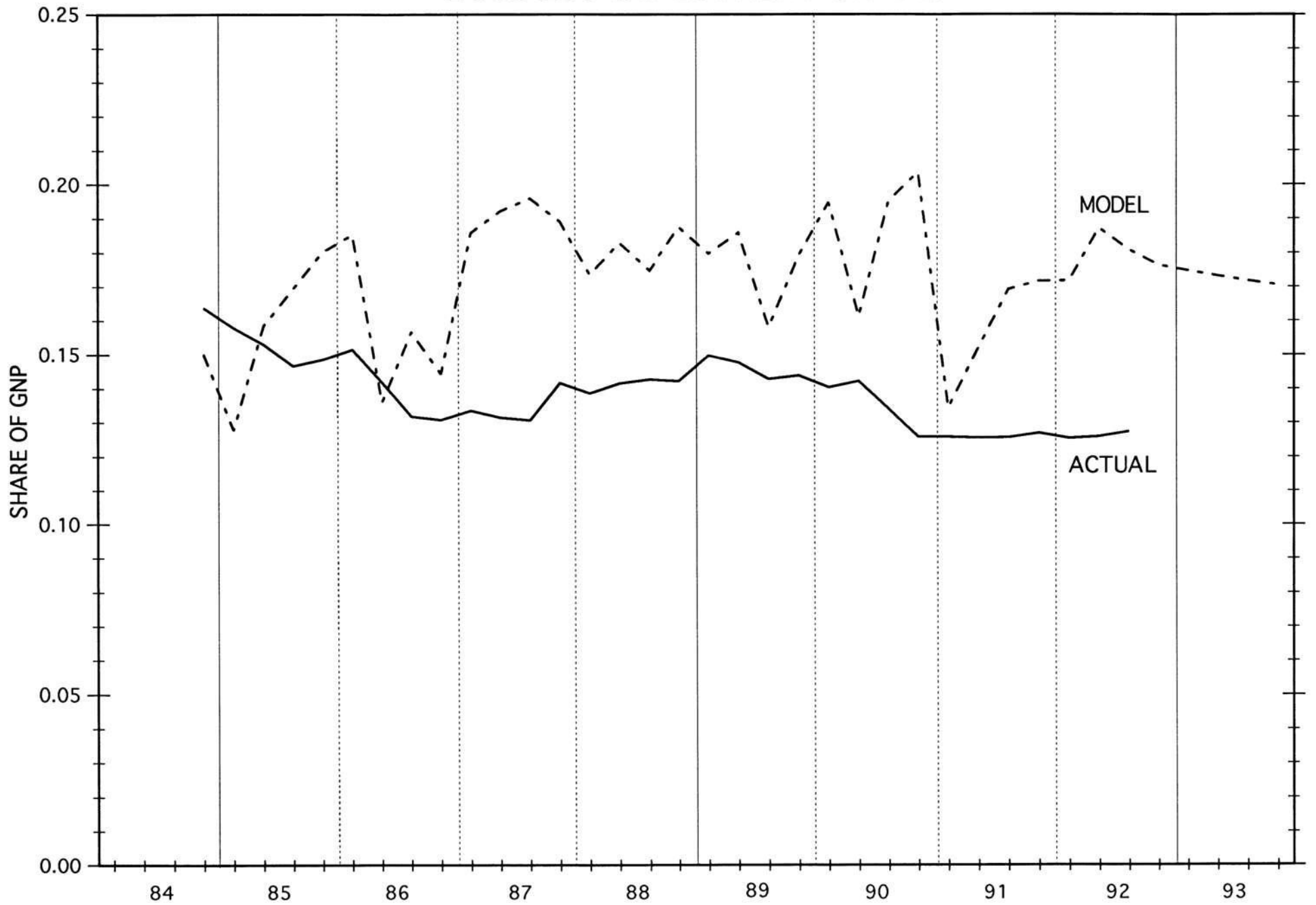LABOR PRODUCTIVITY

FIGURE 6
LABOR INPUT PER ADULT

FIGURE 7
BUSINESS INVESTMENT SHARE

VI. Discussion

The recovery from the recession in the U.S. economy has not been as fast as in the model economy. As we have pointed out, the model economy tends to adjust more quickly than the actual economy to technology shocks. In addition, there are factors other than technology shocks that have real consequences and may have inhibited the recovery. Perhaps changing demographics and life cycle factors leading to lower savings rates are partly responsible for the slow recovery. Perhaps public finance shocks are responsible. People, for example, may be expecting the effective marginal tax on capital income to be higher in the future. Alternatively, people may be anticipating the institution of investment tax credits that will lower the effective price of new capital and, as a result, businesses are deferring investments.

But, insofar as there are no significant public finance shocks, this quantitative theoretical exercise leads us to forecast reasonably rapid growth for a few quarters as real GNP converges to the path predicted by the model. In addition, if future technology shocks are of average values, the longer run prognosis is not so optimistic. This can be seen in the predicted path of GNP for the model economy beyond 1992:3, as shown in Figure 4. Of course, if technology shocks continue to be above average, the U.S. will experience a boom; if the shocks in the coming year are below average, we can expect a recession. The final outcome depends on the nature of the economic institutions—the legal, regulatory and political environment—currently in place and changes that occur over the next year or so.

Notes

[1]The hours series used is a smoothed version of the series plotted in Figure 1. The smoothing was to better seasonal adjustment and to reduce sampling error problems.

[2]We assign all Compensation of Employees, fraction θ_2 of Proprietors' Income, fraction θ_2 of the Statistical Discrepancy, and one-half of Indirect Business Taxes to labor income.

[3]The price of land relative to the consumption good grows in steady-state at rate $\gamma - 1$, which is the rate at which per adult consumption grows.

[4]The calibrated parameter values are $\lambda = 1.000$, $\lambda_d = 1.005$, $\lambda_k = 1.003$, $\rho = 0.95$, $\rho_d = 1.00$, $\rho_k = 1.00$, $\bar{z} = 0.0331$, $\delta_d = 0.051$, $\delta_k = 0.014$, $\theta_1 = 0.26$, $\theta_2 = 0.69$, $\beta = 0.98$, $\sigma = 0.88$, $\alpha = 2.625$, $\eta = 1.0032$. Rates are quarterly.

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