ARE CONSUMER DURABLES IMPORTANT FOR BUSINESS CYCLES?

Marianne Baxter*

Abstract—This paper investigates whether consumer durables are important for the generation and propagation of business cycles. We construct a two-sector model that succeeds in generating business cycles that mimic empirical patterns of cross-sector volatility and comovement. We find that half the relatively higher volatility associated with the durable-goods sector is due to higher volatility of shocks hitting this sector, with the other half due to endogenous responses, notably the investment accelerator. Nevertheless, this model does not have stronger internal propagation than the one-sector model. Further, incorporating durable consumer goods has little effect on the behavior of other macroeconomic variables.

I. Introduction

CONSUMER durables are widely thought to play a central role in the generation and propagation of business cycles. In fact, Mankiw (1985) has stated that "Understanding fluctuations in consumer purchases of durables is vital for understanding economic fluctuations generally."[1] This paper seeks to evaluate whether consumer durables are important for fluctuations in aggregate economic activity by asking several related questions. First, do consumer durables represent an important propagation mechanism, by which temporary shocks to the economy can have long-lasting effects? Second, does this model overcome the "comovement problem" which plagues one-sector real business cycle models?[2] Third, is the well-known volatility of consumer durables and investment due to endogenous mechanisms of the economy, or is it rather due to the fact that the shocks which impinge on the capital-producing sector are simply more volatile?

The paper is structured as follows. Section II develops a two-sector neoclassical model of a closed economy which is used to study the relationship between consumer durables and the business cycle. In this model, there are both durable and nondurable goods; the durable good can be used as a consumer good as well as an investment good. Section III describes the parameterization of the model and the measurement of the sectoral Solow residuals which are used to drive the model. In section IV we investigate the role of consumer durables in the generation and propagation of business cycles. This section focuses specifically on the role of consumer durables in generating endogenous volatility in the durables-producing sector, and in strengthening internal propagation, relative to the one-sector model. We also investigate whether the durability, per se, of consumer durables is important for understanding business cycles. Section V concludes with a brief review of the paper's main results.

Received for publication March 1, 1993. Revision accepted for publication November 14, 1994.

*University of Virginia.

This project has benefited from the comments and suggestions of Thomas Cooley, George Evans, Jeremy Greenwood, Zvi Hercowitz, Urban Jermann, Robert King, Michael Kouparitsas, Robert E. Lucas, Jr., Rodolfo Manuelli, Masao Ogaki, Eric van Wincoop, and three anonymous referees. In addition, I am grateful to Matthew Shapiro for providing his sectoral database. Hsiang-Ling Han and Matthew van Vlack provided excellent research assistance. None of these individuals is responsible for any errors or omissions. The support of the National Science Foundation is gratefully acknowledged.

[1] Mankiw (1985) p. 353, paragraph 2.

[2] The "comovement problem" is the strong tendency for the one-sector, multi-location (or multi-country) model to generate negative comovement of labor input and investment across locations unless the shocks are extremely highly correlated across the different locations. See, for example, Rebelo (1989).

II. The Model

This section describes a two-sector, two-factor equilibrium model of a closed economy which we employ as a laboratory for studying sectoral business cycles. Sector 1 produces a nondurable, pure consumption good. Sector 2 produces the consumer durable and also produces the capital good used in both sectors. The two factors of production are homogeneous labor and capital. We follow Bernanke (1985) and Startz (1989) in specifying adjustment costs which are incurred in altering the stocks of consumer durables, although our specification differs from theirs in the details.

A. Preferences

The representative consumer receives utility from three sources: consumption of the nondurable consumer good, consumption of the service flow from the durable consumption good, and consumption of leisure. The nondurable consumption good is an aggregate of all the nondurable goods purchased by consumers: the major components are food, clothing, fuels, transportation, and medical care. The durable consumption good is an aggregate which includes the NIPA definition of durable goods (motor vehicles, furniture, stereos, televisions, boats, jewelry, and books), combined with the stock of residential housing. Let C_{1t} denote period t consumption of the nondurable consumption good and let C_{2t} denote consumption of the service flow from the durable consumption good. Define C_t^* as the following function of the two consumption goods:

$$C_t^* = \varphi(C_{1t}, C_{2t}) \tag{1}$$

where φ is homogeneous of degree one in C_1 and C_2, with $\partial\varphi/\partial C_j > 0$ and $\partial^2\varphi/(\partial C_j)^2 < 0$ for $j = 1,2$. The elasticity of substitution of good 1 for good 2 is denoted ζ_{12} with $0 \le \zeta_{12} < \infty$. The service flow from the durable consumption good is assumed to be proportional to the stock of the durable consumption good, S_t:

$$C_{2t} = \nu S_t,\ \nu > 0. \tag{2}$$

The representative consumer maximizes expected lifetime utility, given by

$$U = E_0 \sum_{t=0}^{\infty} \beta^t \frac{1}{1-\sigma}\left[\left(C_t^* v(L_t)\right)^{1-\sigma} - 1\right],$$

with $\sigma > 0$ and $\sigma \neq 1$, (3)

and

$$U = E_0 \sum_{t=0}^{\infty} \beta^t \left\{ \log\left(C_t^*\right) + \upsilon\left(L_t\right) \right\} \text{ for } \sigma = 1, \tag{4}$$

where β is the individual's subjective rate of time discount, L_t denotes leisure, and $\upsilon(L_t)$ measures the utility gained from leisure with $\upsilon' > 0$, $\upsilon'' < 0$.

B. Technology

The two final goods produced by the economy are a perishable consumption good, produced in sector 1; and a capital good, produced in sector 2. Sector 2 provides new investment goods to both sectors and also produces the consumer durable. The two factors of production are homogeneous labor and capital. Both sectors require the use of both factors, although they may use them in different proportions. The two goods are produced via Cobb-Douglas production functions, as follows:

$$Y_{1t} = F_{1t}\left(K_{1t}, N_{1t}\right) = A_{1t}\left(X_{K1t}K_{1t}\right)^{\alpha_1}\left(X_{N1t}N_{1t}\right)^{1-\alpha_1} \tag{5}$$

$$Y_{2t} = F_{2t}\left(K_{2t}, N_{2t}\right) = A_{2t}\left(X_{K2t}K_{2t}\right)^{\alpha_2}\left(X_{N2t}N_{2t}\right)^{1-\alpha_2} \tag{6}$$

where K_{jt}, N_{jt} denote capital and labor used in producing sector j output at time t ($j = 1,2$). A_{jt} denotes the stochastic component of total factor augmenting technical change in sector j at time t; A_{jt} may contain both permanent and temporary components. X_{ijt} denotes the level of the deterministic trend component of factor i augmenting technical change in sector j in period t; the X_{ijt} are assumed to grow at constant geometric rates, γ_{Xij} where we define $\gamma_Z \equiv Z_{t+1}/Z_t$. The following restrictions must be satisfied for the economy to display steady state growth (i.e., a situation in which one sector does not eventually represent all of GNP). First, $\gamma_{XK2} = 1$; permanent technical change in the capital-producing sector must be purely labor-augmenting. Second, there may be capital-augmenting technical change in the nondurables sector, $\gamma_{XK1} > 1$, but the following restriction must be satisfied:

$$\frac{\gamma_{XN1}}{\gamma_{XK1}} = \gamma_{XN2}.$$

In response to shocks to the economy, there will be reallocations of capital and labor across sectors. Although labor is assumed to be freely, instantaneously mobile across sectors, we assume that adjustments in capital stocks are subject to convex costs of adjustment. Specifically, we assume that the stocks of productive capital in the two sectors and the stock of consumer durables evolve as follows. Letting I_{jt} denote gross investment in sector j in period t, and letting D_t denote purchases of new consumer durables, we assume the following:

$$K_{1,t+1} = \left(1-\delta_1\right)K_{1t} + \phi_K\left(I_{1t}/K_{1t}\right)K_{1t} \tag{7}$$

$$K_{2,t+1} = \left(1-\delta_2\right)K_{2t} + \phi_K\left(I_{2t}/K_{2t}\right)K_{2t} \tag{8}$$

$$S_{t+1} = \left(1-\delta_S\right)S_t + \phi_S\left(D_t/S_t\right)S_t, \tag{9}$$

where the adjustment cost functions are assumed to satisfy $\phi_j > 0$, $\phi'_j > 0$, and $\phi''_j < 0$, for $j = K, S$. Note that the adjustment cost function for consumer durables may differ from that for capital goods (although it is assumed to be the same for capital in the two output sectors), and depreciation rates may vary by type of capital.

C. Resource Constraints

Resource constraints for this economy are as follows. First, leisure plus hours of work in each of the two sectors cannot exceed the individual's allocation of time, which we normalize to 1:

$$N_{1t} + N_{2t} + L_t \leq 1. \tag{10}$$

Second, there are resource constraints for each of the two final goods. For the sector producing the pure consumption good, the constraint is

$$C_{1t} \leq Y_{1t}. \tag{11}$$

For the sector producing the capital good, the constraint is

$$D_t + I_{1t} + I_{2t} \leq Y_{2t}. \tag{12}$$

Preferences and technology have been restricted so that the economy will exhibit balanced growth in the steady state. The model is solved by forming a Lagrangian, constructing the first-order necessary conditions (the "Euler equations"), and then using numerical methods to find log-linear approximations to the decision rules that solve this system of equations. Specifically, we employ King, Plosser, and Rebelo's (1987) log-linear version of the general Euler equation approach to solving nonlinear dynamic models.

III. Calibration and Driving Shocks

Since we wish to obtain quantitative predictions from our model, we must have numerical values for the key parameter values. For the most part, the model is calibrated from U.S. sectoral data constructed as described more fully in section IV below. Wherever possible, we use parameters estimated in previous empirical studies.

A. Preferences

The parameter β determines the steady state level of the real interest rate in the economy. We choose β so that the annual real interest rate is 6.5%. The parameter σ is the inverse of the elasticity of intertemporal substitution. Previous estimates using aggregate consumption data have yielded estimates of σ in the range 0.2 to 50. In particular, Mankiw (1985), Bernanke (1985), and Eichenbaum and Hansen (1990) have estimated this parameter for models incorporating consumer durables as well as nondurables. Neither Mankiw nor Bernanke could reject the hypothesis that consumer durables and nondurables enter the utility function in a separable fashion (in their specification, this implies $\sigma = 1$). By contrast, Eichenbaum and Hansen reject the hypothesis that durables and nondurables enter separably in the utility function. We find that our model provides a better match to the data when individuals are somewhat more risk averse than the log case: our benchmark value of σ is 1.5.

There are three additional preference parameters that must be specified: (i) the steady-state shares of C_1 and C_2 as fractions of C^*; (ii) ζ_{12}, the elasticity of substitution of good 1 for good 2; and (iii) the own-elasticity of the marginal utility of leisure, ζ_{LL}.[3] The steady state shares of C_1 and C_2 were calibrated as the sample averages over the period 1948–1985, yielding $\theta_1 \equiv (C_1/C^*) = .785$ and $\theta_2 = 1 - \theta_1$. The other two parameters, ζ_{12} and ξ_{LL} are calibrated as follows. First, for the model to generate positive contemporaneous correlation of N_1 and N_2, as observed in the data, the two goods cannot be extremely good substitutes in consumption. Given our value for σ, the model generates realistic labor comovement for values of ζ_{12} between 0.5 and 2.5. We choose $\zeta_{12} = 1.5$ as our benchmark. Second, the elasticity ξ_{LL} primarily governs the aggregate labor supply response to shocks. Given our specification of utility and our parameterization of σ and ζ_{12} there is a lower bound placed on the absolute value of ξ_{LL} which will deliver concavity of momentary utility. We set ξ_{LL} equal to –1.3, which is close to this bound.

B. Technology

Shares: For the two sectors in our economy, constructed as described in section IV.A below, labor's share in each sector is computed as total worker compensation divided by total output in that sector. The average value of labor's share in durables is 0.68, and is 0.48 in nondurables.

Ratio of average product: A second parameter necessary for solution of the model is the ratio of the average product of labor in sector 1 to the average product of labor in sector 2. Average product in each sector is computed as real output in that sector divided by total hours. The ratio of average product in sector 1 to average product in sector 2 has a mean of 0.84.

Depreciation rates: The depreciation rates for the two capital goods and the consumer durable were parameterized as follows. First, Bernanke (1985) reports an estimated quarterly depreciation rate for consumer durables of 5.06%, or an annual rate of 22%. However, residential capital accounts for about 35% of our measure of consumer durables, and houses depreciate much more slowly than, say, stereos. With a useful life of 27 years (according to the IRS), straight-line depreciation implies an annual depreciation rate for housing of 3.7%. The weighted-average depreciation rate for aggregate consumer durables is thus 15.6%.

For capital used in production, the July 1985 Survey of Current Business reported new computations of useful service lives for capital used in producing several categories of manufacturing durable and nondurable goods. The average lifespan of a machine in the durable goods sector is about 14 years. Translated to annual depreciation rates, assuming straight-line depreciation over the useful service life yields $\delta_K = 7.1\%$.

Adjustment costs: The adjustment cost functions were parameterized as follows. First, we assume that there are no adjustment costs incurred in maintaining the steady state levels of capital and consumer durables. Thus, in the steady state, $\phi_K(i_j/k_j) = i_j/k_j$ for $j = 1, 2$, and $\phi_s(d/s) = d/s$. Second, we assume that in the steady state Tobin's q (the ratio of the price of existing capital to the price of new capital) is one for both types of capital and the durable good. This implies that $\phi'(i_j/k_j) = 1$ for $j = 1, 2$, and $\phi'(d/s) = 1$. Finally, we must specify the elasticities of (i_j/k_j) and (d/s) to movements in the appropriate relative price (i.e., the appropriate version of Tobin's q). We assume that this elasticity, denoted η, is the same across sectors. Calibrating this parameter is difficult, as there are no directly-applicable empirical studies that have estimated these elasticities. Since η primarily affects investment volatilities and cross-sector correlations of labor input and investment, these moments are used to restrict η. In the benchmark parameterization, we set $\eta = 200$.

C. Stochastic Process for Solow Residuals

Computing the sectoral Solow residuals requires data on labor and capital shares in total output. We have assumed that production functions are Cobb-Douglas and constant-returns-to-scale. Letting α_j denote capital's share in sector j, the sectoral Solow residuals are defined in standard fashion as movements in output that cannot be explained by movements in factor inputs:

$$SR_{jt} = \log(Y_{jt}) - \alpha_j \log(K_{jt}) - (1-\alpha_j)\log(N_{jt}); j = 1,2. \quad (13)$$

Table 1 provides summary statistics on these measures of sectoral productivity. Productivity growth has proceeded at a higher average rate in the durables sector, growing at 5.0% per year compared with average growth of 4.4% per year in

TABLE 1.—SUMMARY STATISTICS FOR SOLOW RESIDUALS (GROWTH RATES OF ANNUAL DATA, 1948–1985)

	Mean: %Per Year	Std. Dev.: % Per Year	First-order Autocorrelation
Nondurables	4.39	2.56	0.51
Durables	5.03	3.26	0.19
Correlation between nondurables and durables:			0.69

[3] The parameter ν does not affect any of the dynamic properties of the model.

TABLE 2.—STOCHASTIC PROCESS FOR SOLOW RESIDUALS

ΔSR_{1t}	$= -0.012$ (0.030)	$-0.072\, \Delta SR_{1,t-1}$ (0.173)	$-\ 0.025\, (SR_{1,t-1} - SR_{2,t-1}) + u_{1t}$ (0.040)
$(SR_{1t}-SR_{2t})$	$= -0.050$ (0.046)	$-0.184\, \Delta SR_{1,t-1} +$ (0.262)	$0.932\, (SR_{1,t-1} - SR_{2,t-1} -1) + u_{2t}$ (0.061)

Implied variance-covariance matrix for innovations to sectoral Solow residuals:

$$\Sigma = \begin{bmatrix} (1.152 \times 10^{-2})^2 & 2.24 \times 10^{-4} \\ 2.241 \times 10^{-4} & (2.518 \times 10^{-2})^2 \end{bmatrix}$$

correlation between u_1 and u_2: 0.77

Notes: Annual data, 1948–1985. Standard errors are in parentheses.

nondurables. This table also shows that (i) productivity growth in durables is more volatile and less persistent than in nondurables, and (ii) there is substantial positive correlation between productivity growth in durables and nondurables: the correlation coefficient is 0.69.

Since the Solow residuals in the two sectors are difference stationary and appear to be cointegrated (see Baxter (1992) for details), the stochastic process for the sectoral Solow residuals is estimated as

$$\begin{bmatrix} \Delta SR_{1t} \\ SR_{1t} - SR_{2t} \end{bmatrix} = \begin{bmatrix} k_1 \\ k_2 \end{bmatrix} + \begin{bmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{bmatrix} \begin{bmatrix} \Delta SR_{1,t-1} \\ SR_{1,t-1} - SR_{2,t-1} \end{bmatrix} + \begin{bmatrix} u_{1t} \\ u_{2t} \end{bmatrix} \tag{14}$$

where ΔSR_{jt} denotes the growth rate of the Solow residual in sector j in period t. Estimates were obtained by running two OLS regressions, and the results of this estimation are reported in table 2. This process was used to drive our model; the results are presented in the next section.

IV. Productivity and Sectoral Business Cycles

The real business cycle research program has discovered that the standard, one-sector neoclassical model is capable of reproducing many important business-cycle regularities when driven by aggregate Solow residuals. Although this approach is highly controversial, the fact remains that this model does surprisingly well along many dimensions when it is driven by an exogenous productivity process with the same time series properties possessed by aggregate Solow residuals.

The one-sector model nevertheless has several empirical shortcomings: two of the most important are as follows. First, the model does not contain a strong internal propagation mechanism. For the model to produce sustained fluctuations in output, consumption, investment, etc., the shocks to the model must themselves be sustained over time. Second, the one-sector model is unable to produce realistic comovement in output and labor supply across different locations. Recently, Benhabib, Rogerson, and Wright (1991) stressed a third shortcoming of the one-sector model—that hours of work devoted to production of consumption goods are negatively correlated with hours of work devoted to production of investment goods.

The two-sector model with consumer durables may be able to improve the predictions of the standard neoclassical model along all three dimensions. First, the fact that consumer durables behave essentially as a capital good provides an additional source of endogenous propagation. Changes in the stock of consumer durables that occur in response to shocks will naturally persist over time since consumer durables depreciate slowly. Second, the comovement problem may be mitigated by the fact that the sectors are linked in two ways. On the consumption side, the two goods are not perfect substitutes. There is a further linkage on the production side, where production of the nondurable good requires the durable good as input. Third, because of the linkages on both the consumption and production sides of the model, hours of work in the two sectors may be positively correlated over the business cycle. This section evaluates the ability of the two-sector model to generate "realistic" business cycles. In particular, we investigate whether the multi-sector character of the model improves the model's propagation and comovement properties when the parameterized model is driven by the estimated process for sectoral Solow residuals.

A. The Data

This section briefly describes the data that we use to evaluate the model. The primary data source is a sectoral database which contains annual, post-war data on factor input, compensation, and output measures for thirteen SIC one-digit industries for the period 1948–1985.[4] Since we want to construct an aggregate economy with only two sectors, the first task is to assign each industry to a particular sector, depending on whether it produces predominantly durable or nondurable goods. Table 3 presents data taken from the 1972 input/output table for the United States. This table shows the breakdown, by industry, of output allocated to final consumption and investment.

Table 3 indicates that most industries are clearly recognizable as producing either consumption goods or investment goods. Industries that produce predominantly consumption goods are agriculture; transport, communication, and utilities; wholesale and retail trade; finance, insurance, and real estate; and services. Based on these statistics, we define the output of "consumption good sector" (sector 1) as the total output of these sectors, plus manufacturing nondurables. Over the sample period the share of nondurables in total output has been rising, and currently is about 78%. The durable goods sector produces output which is used both as new capital goods and consumer durables. The mining and construction sectors have very low consumption shares, and therefore are allocated to the durables sector, together with manufacturing durables. Implicit price deflators were constructed for

[4] This dataset is documented in more detail in Shapiro (1987).

TABLE 3.—SECTORAL OUTPUT BY FINAL USE

Industry	Consumption (%)	Investment (%)
Agriculture	100.0	0.0
Mining	24.4	75.6
Construction	0.0	100.0
Manufacturing	56.9	43.1
Transportation, Communication, & Utilities	92.4	7.6
Wholesale and Retail Trade	93.2	6.8
Finance, Insurance, and Real Estate	97.8	2.2
Services	99.8	0.2

Source: 1972 Input-Output Table of the United States, Department of Commerce.
Note: Entries computed as follows: of the total sectoral output allocated to consumption plus capital formation, this table shows the percentage allocated to each use.

each sector using 1982 as the base year. The relative price of durables in terms of nondurables is constructed as the ratio of the two sectoral implicit price deflators.

Sectoral labor input is defined as total hours applied to production in that sector; capital input is the total sectoral capital stock. Sectoral investment was computed from the capital stock data assuming a depreciation rate of 7.1% per year. Nominal sectoral wages were computed as the weighted average of nominal compensation per manhour in the subsectors, with the weights being the current value of the sectoral output share accounted for by the particular subsector. Nominal wages were converted to sectoral real wages using the NIPA sectoral implicit price deflators. The average value of labor's share in durables is 0.68, compared with 0.48 in nondurables (labor's share is computed as total worker compensation in a sector divided by aggregate sectoral output). The higher value of labor's share in durables primarily reflects the higher wage rate in durables, rather than higher labor intensity in this sector.

To construct a measure of purchases of consumer nondurables, we added together NIPA nondurables plus services, then subtracted the imputed rental on owner-occupied housing. The NIPA measure of purchases of consumer durables does not include residential investment. We assume that completed housing units are occupied immediately, thus we measured purchases of new consumer durables as the sum of the NIPA measure of consumer durables purchases plus the net addition to the residential housing stock. The share of residential investment in this new aggregate for consumer durables is approximately 35%. With these new aggregates for consumer durables and nondurables, durables represent a larger average share of total consumption expenditure. Using the new aggregates, the average share of durables in total consumption expenditure is about 23%, compared with about 12% using the standard measures.

B. Business Cycles in the Two-sector Model

This section evaluates the extent to which the two-sector model reproduces the key qualitative features of sectoral business cycles. Table 4 provides statistics summarizing the model's predictions for sectoral volatility, persistence, and comovement. These predictions are compared with corresponding moments from the data. Both the model and the data have been filtered with the Hodrick-Prescott (1980) filter with the smoothing parameter $\lambda = 400$.

TABLE 4.—BUSINESS CYCLES IN THE TWO-SECTOR MODEL

I. CYCLIC VOLATILITY (PERCENT PER YEAR)

Variable		Nondurables	Durables
Output	model	1.72	4.80
	data	1.77	5.63
Investment	model	5.52	9.44
	data	7.03	15.14
Hours	model	0.20	1.98
	data	1.55	5.97
Capital stock	model	1.61	2.01
	data	1.75	2.84
Consumption purchases	model	1.72	5.04
	data	1.77	8.86
Wages	model	1.64	2.97
	data	1.09	2.14
Relative price	model	—	2.26
	data	—	2.96

II. PERSISTENCE (FIRST-ORDER SERIAL CORRELATION)

Variable		Nondurables	Durables
Output	model	.76	.76
	data	.42	.49
Investment	model	.69	.41
	data	.53	.60
Hours	model	.53	.77
	data	.32	.46
Capital stock	model	.96	.92
	data	.88	.82
Consumption purchases	model	.76	.38
	data	.56	.39
Wages	model	.81	.78
	data	.12	.64
Relative price	model	—	.79
	data	—	.65

Panel I of this table compares cyclic volatility in the model to that in the data. The model predicts that output, investment, hours, and consumption purchases are more volatile in durables than in nondurables, as is true in the data. For sectoral outputs, the model predicts volatility statistics that are close to those found in the data. In the case of investment, predicted volatility in each sector is too low, although the model does capture the general feature that investment in nondurables is about half as volatile as investment in durables. Predicted volatility of consumer durables purchases is also low, but is correctly predicted to be substantially more volatile than purchases of nondurables.

The predicted volatility of hours in each sector is too low. However the volatility of hours in durables is correctly pre-

TABLE 4.—(*Continued*)
III. CONTEMPORANEOUS CORRELATIONS

		Y:nd	Y:d	I:nd	I:d	H:nd	H:d	C:nd	C:d	W:nd	W:d	P
Output	model	1	.58	.45	.39	.45	.35	1	.47	.99	.71	−.20
nondur.	data		.77	.50	.54	.88	.74	.69	.42	−.12	−.09	−.11
Output	model		1	.58	.83	.75	.96	.58	.87	.52	.98	−.91
durable	data			.41	.69	.82	.94	.58	.20	−.29	−.09	−.11
Investment	model			1	.03	.03	.46	.45	.11	.46	.62	−.48
nondur.	data				.38	.37	.19	.73	.65	.02	.33	−.54
Investment	model				1	.91	.87	.39	.98	.30	.77	−.79
durable	data					.44	.59	.40	.40	−.02	−.30	.20
Hours	model					1	.79	.45	.85	.35	.68	−.63
nondur.	data						.87	.57	.12	−.38	−.14	−.13
Hours	model						1	.35	.86	.27	.88	−.97
durable	data							.46	−.02	−.32	−.27	.09
Consumption	model							1	.47	.99	.71	−.20
nondur.	data								.57	.03	.24	−.30
Consumption	model								1	.39	.83	−.81
durable	data									.37	.33	−.28
Wages	model									1	.66	−.14
nondur.	data										.06	.30
Wage	model										1	−.84
durable	data											−.84
Relative price												1

Note: In each cell, the top number is the Hodrick–Prescott filtered model prediction and the bottom number is computed from the filtered data.

dicted to be higher than volatility in nondurables. The volatility of the relative price is somewhat low in the model compared with the data.

In terms of persistence of movements in macro aggregates (measured as the first-order serial correlation coefficient) the model generally predicts higher persistence than is found in the data, as shown in panel II of table 4. The one exception is purchases of consumer durables, where the model matches the low persistence in the data almost exactly. Nevertheless, the internal propagation mechanisms of this two-sector model are no stronger than those of the one-sector model. When the model is driven by productivity shocks with zero first-order serial correlation, output, consumption, investment, and labor supply also display approximately zero persistence (these results are not in the table).

The contemporaneous correlation structure of the model is presented in panel III of table 4. In many respects, the model does a good job of matching the correlations found in the data. First, within each sector, the model predicts that hours, investment, and consumption purchases are positively correlated with output, as is true in the data. Second, and more importantly, the model correctly predicts that the cross-sectoral correlations of output, investment, hours, and consumption purchases are positive. Thus the sectoral interdependencies built into the model solve the "comovement problem."[5] In particular, the model predicts that hours of work devoted to producing consumption goods are positively correlated with hours of work devoted to producing investment goods, a phenomenon which Benhabib et al. (1991) have argued is an important feature of business cycles.

More problematic are the model's predictions for the behavior of wages and relative prices. Here, the model's predicted correlations do not generally line up well with the data. In particular, the model predicts a strong positive correlation between sectoral wage rates and sectoral output, while these are roughly uncorrelated in the data. In the case of wage rates, this may be due to the fact that real wages as measured in the NIPA are not a good measure of the contemporaneous marginal product of labor, for reasons expounded by a number of authors. Or, the model may omit important sources of shocks which operate on the "demand side," such as government spending shocks or preference shocks.[6]

Finally, panel IV of table 4 presents the cross-correlations of the key macro aggregates with sectoral output. Although the model correctly predicts that purchases of durables are strongly correlated with output of durables both contemporaneously and also at the first lag, the highest correlation in the model is contemporaneous, while in the data the highest correlation is at the first lag (i.e., durables "lead the cycle"). This phenomenon also holds with respect to the investment–output relationship within each sector. Otherwise, the

[5] See also a recent paper by Reynolds (1992) which studies a two-good, open economy model with production and consumption linkages. She also finds that the multi-sector character of the economy is central to resolving the comovement problem.

[6] However, Baxter (1992) shows that preference shocks cannot be the sole source of business cycles in this two-sector model; see also the analysis of preference shocks in Baxter and King (1991).

TABLE 4.—(CONTINUED)
IV. CROSS CORRELATION WITH SECTORAL OUTPUT

Variable		$i = 2$	$i = 1$	$i = 0$	$i = -1$	$i = -2$
		A. Nondurables				
		Correlation (Variable(t), output($t-i$))				
Investment	model	0.14	0.36	0.58	0.48	0.48
	data	−0.30	−0.06	0.50	0.81	0.3
Hours	model	−0.15	0.06	0.45	0.29	0.27
	data	−0.13	0.48	0.87	0.15	−0.18
Consumption	model	0.63	0.76	1.00	0.76	0.63
(purchases)	data	−0.05	0.19	0.69	0.69	0.24
Wages	model	0.68	0.79	0.99	0.77	0.63
	data	0.27	−0.07	−0.13	0.24	0.14
Relative price	model	0.12	−0.07	−0.20	−0.20	−0.27
	data	0.51	0.14	−0.10	−0.31	−0.36
		B. Durables				
		Correlation (Variable(t), output($t-i$))				
Investment	model	−0.02	0.24	0.83	0.71	0.52
	data	−0.09	0.25	0.69	0.71	0.11
Hours	model	0.36	0.67	0.96	0.78	0.56
	data	0.10	0.61	0.93	0.26	−0.21
Consumption	model	0.16	0.36	0.87	0.71	0.49
(purchases)	data	−0.20	−0.29	0.21	0.64	0.27
Wages	model	0.58	0.79	0.98	0.72	0.45
	data	−0.19	−0.01	−0.00	0.12	0.12
Relative price	model	−0.40	−0.69	−0.91	−0.73	−0.53
	data	0.34	0.01	−0.19	−0.27	−0.21

model's predictions for these cross-correlations are roughly in line with the data.

C. The Causes of Sectoral Volatility

Why is the durables sector more volatile than the nondurables sector, both in the model and in the data? Is this phenomenon due to the higher volatility of shocks to durables, or is it an endogenous economic response? To investigate this question, we set the innovation variance in the durables sector equal to that in the nondurables sector, while preserving the cross-sectoral correlation of the shocks (this involves reducing by about one-half the standard deviation of the shocks to durables). Table 5 presents sectoral volatility statistics for this case. Evidently, reducing the volatility of shocks in durables reduces the volatility of both sectors, but understandably reduces volatility more in the durables sector. Nevertheless, volatility in the durables sector exceeds volatility in nondurables, although by about half the level obtained in the benchmark parameterization. Thus we conclude that about 50% of the higher volatility found in the durables sector is due to the endogenous mechanisms of the economy—notably the investment accelerator which operates both on consumer durables and investment goods. The remaining 50% is due to the fact that the shocks which impinge on the durable-goods industry are simply more volatile.

D. Is Durability Important?

Is the durability, per se, of consumer durables important for the character of business cycles in this two-sector model? In particular, does the durability of this consumption good increase the persistence of the model's response to shocks? To answer this question, we set the depreciation rate of con-

TABLE 5.—THE SOURCES OF CYCLIC VOLATILITY
(STANDARD DEVIATIONS, PERCENT PER YEAR)

Variable	Model Variant	Nondurables	Durables
Output	benchmark	1.72	4.80
	equal variance	1.48	2.17
Investment	benchmark	5.52	9.44
	equal variance	2.47	3.99
Hours	benchmark	0.20	1.98
	equal variance	0.14	0.81
Capital stock	benchmark	1.61	2.01
	equal variance	0.76	0.89
Consumption purchases	benchmark	1.72	5.04
	equal variance	1.48	2.02
Wages	benchmark	1.64	2.97
	equal variance	1.37	1.45
Relative price	benchmark	—	2.26
	equal variance	—	0.91

Note: The equal variance model sets both sectors' innovation variances equal to the innovation variance in nondurables used in the benchmark case, and preserves the contemporaneous correlation of the sectoral shocks.

sumer durables at 100% (per quarter) and recomputed the model's predictions (not reported in the tables). It was striking how little difference this change made to the model's predictions; the only notable alterations were as follows. First, with 100% depreciation, the volatility of consumer durables dropped from 5.04% per year to 3.62%. At the same time, the persistence of consumer durables increased from 0.38 to 0.75 (with 100% depreciation, persistence is approximately the same for consumer durables and nondurables), while investment volatility in the durables sector increases from 9.44% to 11.21%. Finally, the cross-sector correlation of labor inputs drops from 0.79 to 0.01. Aside from these changes, the model's predictions are largely insensitive to the depreciation rate for consumer durables.

E. Common Shocks

For comparison with the results above, we examined the model's predictions when driven by a single, unit-root productivity process that is shared by both sectors. One might guess that this process could generate the observed higher volatility of both output and consumption purchases in the durables sector because this sector produces the investment goods (including consumer durables) for which demand is highly volatile. However, this case fails to explain many of the important features of sectoral business cycles. First, the predicted volatility of the durables sector under "common shocks" is only 1.25 times as high as volatility of nondurables, compared with 3.18 times as high in the data, and 2.80 in our benchmark model. Second, the "common shock" process leads purchases of consumer durables to be *less* volatile than output of the durables sector, which is counterfactual. Specifically, the common-shock model predicts the relative volatility of purchases of consumer durables to be 0.69 times as volatile as output, compared with 1.57 times as volatile in the data, and 1.05 times as volatile in our benchmark model (see table 4). Even worse is the prediction that purchases of consumer durables are substantially less volatile than purchases of consumer nondurables. We investigated whether this was due to adjustment costs in consumer durables, and found that this was not the case. Rather, the common shock feature of the process means that investment demand in both production sectors rises sharply at the same time, driving up the relative price of the durable consumption good. Since the nondurable consumption good can be used to generate utility, the effect and general equilibrium is for purchases of nondurables to rise more sharply in response to a positive productivity shock than purchases of durables. A further problem with the common-shock theory is that cross-sectoral correlations of output, investment, labor input, and consumption are all predicted to be 0.99, which is much too high relative to the data.

F. Random-walk Productivity

Another interesting alternative hypothesis concerning productivity is that the two sectoral shocks are random walks, but with less-than-perfectly-correlated innovations. We conducted the experiment of simulating the model with random walk productivity, with the correlation of the innovations set equal to 0.77, as in table 2. As with the common-shock case, the volatility of output in the durable-goods sector is too low, being only about 25% more volatile than output of nondurables. The volatility of consumption of nondurables is now too high, being about as volatile as output of nondurables, while investment volatility in the nondurables sector is too low (about 1.40 times as volatile as output). In the durables sector, relative volatilities of both consumption and investment are too low: consumption purchases are only 1.05 times as volatile as output, while investment is only 1.70 times as volatile.

In terms of cross-sector correlations, those for output and investment are slightly improved under this parameterization, relative to our benchmark: the cross-sectoral correlation of output is 0.72; for investment the figure is 0.36 (see table 4 for data and benchmark model figures). The cross-sectoral correlations for labor input, consumption, and wage rates are worse in the random walk case, with the predicted correlations being 0.72 for labor input; 0.35 for consumption; and 0.99 for wage rates. In terms of persistence and other cross-correlations, this parameterization performs similarly to the one driven by the estimated process for Solow residuals.

V. Conclusions

This paper studies the properties of sectoral business cycles in the post-war United States, with the specific aim of evaluating the role of consumer durables in the generation and propagation of business cycles. Toward this end we developed a two-sector neoclassical model of a closed economy and used this model as a laboratory for studying the interaction of consumer durables and business cycles. When the two-sector model is driven by the estimated process for the sectoral Solow residuals, it is capable of broadly replicating the observed patterns of cyclic volatility. More importantly, there is no "comovement problem" in this model: the model correctly predicts positive cross-sectoral comovement of outputs, investments, and labor inputs. However, the model has more difficulty replicating the business-cycle properties of wage rates and relative prices.

We investigated the source of the higher volatility in the durable goods industry, and found that roughly half of the higher volatility in the durable goods industry is due to the higher volatility of productivity shocks in that industry, with the remaining half due to the endogenous accelerator mechanism. Finally, we investigated whether the durability, per se, of consumer durables was important for business cycles generated by the model. Somewhat surprisingly, we found that the model's predictions were largely insensitive to the depreciation rate for consumer durables, except for the volatility and persistence of consumer durables themselves.

REFERENCES

Baxter, Marianne, "Are Consumer Durables Important for Business Cycles?" Rochester Center for Economic Research Working Paper No. 342 (June 1992).

Baxter, Marianne, and Robert King, "Productive Externalities and Business Cycles," Institute for Empirical Macroeconomics Working Paper (Dec. 1991).

Benhabib, Jess, Richard Rogerson, and Randall Wright, "Homework in Macroeconomics: Household Production and Aggregate Fluctuations," *Journal of Political Economy* 99 (6) (Dec. 1991), 1166–1187.

Bernanke, Ben, "Adjustment Costs, Durables, and Aggregate Consumption," *Journal of Monetary Economics* 15 (Jan. 1985), 41–58.

Eichenbaum, Martin, and Lars Hansen, "Estimating Models with Intertemporal Substitution Using Aggregate Time Series Data," *Journal of Business and Economic Statistics* 8 (1) (Jan. 1990), 53–69.

Hodrick, Robert, and Edward Prescott, "Post-War U.S. Business Cycles: An Empirical Investigation," manuscript, Carnegie Mellon University (Nov. 1980).

King, Robert, Charles Plosser, and Sergio Rebelo, "Technical Appendix to Production, Growth, and Business Cycles'," Rochester Center for Economic Research Working Paper (Oct. 1987).

Mankiw, N. Gregory, "Consumer Durables and the Real Interest Rate," this REVIEW 67 (3) (Aug. 1985), 353–362.

Rebelo, Sergio, "Tractable Heterogeneity and Near-Steady-State Dynamics," manuscript, University of Rochester (May 1989).

Reynolds, Patricia, "International Comovements in Production and Consumption: Theory and Evidence," manuscript, Department of Finance, University of Southern California (Nov. 1992).

Shapiro, Matthew "Measuring Market Power in U.S. Industry," National Bureau of Economic Research Working Paper No. 2212 (July 1987).

Startz, Richard, "The Stochastic Behavior of Durable and Nondurable Consumption," this REVIEW 71 (May 1989), 356–363.