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Exit and Entry, Increasing Returns to Specialization, and Business Cycles

Michael B. Devereux Allen C. Head Beverly J. Lapham

Department of Economics
Queen's University
94 University Avenue
Kingston, Ontario, Canada
K7L 3N6

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by

Michael B. Devereux
Queen's University /
University of British Columbia

Allen C. Head
Queen's University

Beverly J. Lapham
Queen's University

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Michael B. Devereux*   Allen C. Head**   Beverly J. Lapham**

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Abstract

The effects of entry and exit by monopolistically competitive intermediate goods producers on equilibrium business cycles are analyzed in the presence of internal returns to scale and external returns to specialization. In the environment studied, market power and endogenous entry and exit, in themselves, have little effect on the propagation of technology shocks. In contrast, internal returns to scale dampen the effects of these shocks while external returns to specialization produce a multiplier which accentuates their effects. The multiplier arises as entry and exit of firms over the business cycle causes endogenous fluctuations in the productivity of intermediate inputs. These endogenous productivity fluctuations cause the Solow residual both to mismeasure technology shocks and to be strongly correlated with government spending shocks. The results also indicate that the extent to which technology shocks can account for aggregate fluctuations may be greater than suggested by competitive real business cycle models.

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*Queen's University and
University of British Columbia

Department of Economics
997-1873 East Mall
University of British Columbia
Vancouver, BC
CANADA V6T 1Z1

**Queen's University

Department of Economics
Queen's University
Kingston, Ontario
CANADA K7L 3N6

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I. Introduction

The measurement of fluctuations in aggregate productivity is a central feature of real business cycle (RBC) theory. In the traditional RBC framework, cycles are driven by aggregate technology shocks. Under the joint hypotheses of constant returns to scale and perfect competition, productivity shocks can be measured by fluctuations in the Solow (1958) "residual". Many authors (notably Hall (1989)), however, have put forward theoretical and empirical evidence questioning the interpretation of fluctuations in the Solow residual as measures of technology shocks. Hall notes that if markets are imperfectly competitive and/or technologies exhibit increasing returns, the Solow residual yields a biased measure of true shifts in the production function. In addition it is well documented that Solow residuals are not invariant to the money supply, government spending, energy prices, and other non-technological factors (e.g. Hall (1989), Evans (1992), and Finn (1992)).

Two explanations for the failure of "invariance" of Solow residuals that Hall puts forward are a) the prevalence of monopolistic competition, and b) the presence of external economies or *thick market* effects. The first explanation is consistent with the observations that firms tend to price above marginal cost and that average profits are low for U.S. industry [1]. This explanation requires that there be increasing returns at the level of the *firm*. The second explanation is based on the idea that an industry's productivity may increase when the output of other industries increases. When aggregate activity rises, all industries may become more efficient, as suggested in the work of Diamond (1982) and Cooper and John (1988). This explanation requires increasing returns only at the *aggregate* level. Empirical support for this view is provided by Caballero and Lyons (1992) who present evidence that increasing returns in U.S. manufacturing are strongest at the aggregate level.

This paper develops a business cycle model of monopolistic competition along the lines of the international trade model of Ethier (1982) and the growth model of Grossman and Helpman (1991). We show that in the presence of cyclical entry and exit of firms, *both*

[1] For the former see Morrison (1990) or Rotemberg and Woodford (1991). As stated by Hall (1989) with regard to the latter, "With free entry and fixed costs, firms will reach a zero-profit equilibrium in which both the original and cost-based Solow residuals will fail invariance."

explanations a) and b) play important roles in the measurement of technology shocks, and in the propagation of business cycle phenomena. The economy is one in which monopolistically competitive intermediate goods producers supply inputs to a competitive final goods sector. Individual intermediate goods producers experience increasing returns at the firm level due both to fixed costs of production and declining marginal costs. In addition there may be a form of increasing returns to specialization at the aggregate level. Such increasing returns exist if, for a given stock of primary factors, final goods output is higher the greater the *number* of specialized intermediate goods produced.

Our approach introduces two new elements to RBC theory: cyclical entry and exit of firms and the external returns to specialization described above. The former is motivated by the observation that exit and entry of firms are strongly cyclical activities. Audretsch and Acs (1992) present evidence that net business formation is strongest during a macroeconomic expansion. Their analysis also suggests that the entry of new firms during an expansion is strongest in those industries where new firms tend to introduce new specialized products. Evidence that entry and exit of firms has strong implications for employment is provided by Davis and Haltiwanger (1990). Based on their analysis of U.S. manufacturing over the period 1972-86 they estimate that 25% of annual gross job destruction can be attributed to establishment deaths and 20% of annual gross job creation to establishment births. Figure 1 illustrates the cyclical nature of entry and exit. Figure 1A shows that net business formation is strongly procyclical. This results from the combined effects of both strongly procyclical incorporation of new firms and strongly countercyclical business failures, as shown in Figures 1B and 1C. An interesting fact conveyed by Figure 1A is that net entry takes place either contemporaneously with or slightly *prior* to an increase in aggregate output. This suggests the role of entry in producing the expansion, rather than reacting to it.

The introduction of increasing returns to specialization provides a direct link between cyclical entry and exit and a thick market effect of the type described by Hall. Profit incentives created by technology shocks generate entry and exit of firms over the cycle. Fluctuations in the number of intermediate inputs result in *endogenous* productivity fluctuations at the aggregate level. Thus the thick market externality is fundamentally linked to the monopolistically competitive market structure. The converse, however, is not true; it is possible to have monopolistic competition without thick market effects. It is the thick market externality, however, that accounts for the divergence of the economy's cyclical properties from those of a standard competition RBC model. Entry and exit and market power in themselves have no effect on the predictions of the model vis-a-vis those of a benchmark competitive economy.

This paper is primarily concerned with the extent to which technology shocks can account for business cycle phenomena in the presence of both internal and external returns to scale. Thus we follow the line of inquiry pursued by Kydland and Prescott (1982) and Hansen (1985). There are two important facets to this exercise. First, the presence of monopolistic competition and increasing returns affects the *propagation* of technology shocks. For given impulse dynamics we characterize the effects of the degree of increasing returns (of both the internal and external variety) on cyclical volatility and the bias in the Solow residual. Second, the introduction of monopolistic competition and increasing returns has implications for the *measurement* of technology shocks. Our model yields a measure of total factor productivity analogous to the Solow residual, and thus enables us to examine the bias inherent in using the latter as a measure of technology shocks, as most RBC studies to date have done.

With regard to the measurement of technology shocks we find that in the presence of increasing returns that are internal to the firm, fluctuations in the Solow residual may *understate* the magnitude of technology shocks. In the presence of increasing returns to specialization, however, the fluctuation in the Solow residual generally *overestimates* the variance of technology shocks. The ability of technology shocks to account for business cycle phenomena, however, rests not only on the magnitude of these shocks, but also on the strength of the economy's propagation mechanism. We find the responses of aggregate variables to a given technology shock are significantly stronger in the presence of increasing returns to specialization. In addition, as the Solow residual measures the endogenous productivity response as well as the effect of the exogenous technology shock, the economy can account for failures of invariance to a wide variety of factors. Any impulse which causes the equilibrium number of firms to fluctuate will produce a procyclical Solow residual. We illustrate this by showing that the model can produce nearly perfect correlation between government spending shocks and the Solow residual.

By combining the two facets of our analysis we are able to address the issue of the share of aggregate fluctuations accounted for by technology shocks. In the absence of increasing returns to specialization, technology shocks account for roughly the same share of aggregate fluctuations in our economy as in a benchmark competitive RBC model. When increasing returns to specialization are present our estimates of both the variance and persistence of technology shocks are reduced relative to those based on the Solow residual. Nevertheless, these technology shocks account for 8% more fluctuation in output than the larger technology shocks do in the competitive model. Thus while monopolistic competition, increasing returns to scale, and thick market externalities reduce our estimates of the magnitude of technology shocks, they may *increase* our estimates of the share of aggregate fluctuations accounted for by these shocks.

There are a number of previous papers related to ours. Hornstein (1992) and Cho (1990) analyze monopolistically competitive environments in which the number of firms is fixed over the cycle. Thus their models do not possess the entry and exit propagation mechanism that is central to our analysis. Ambler and Cardia (1992) study a model in which the number of firms is fixed in the short run but may react to shocks over time. In their framework the number of firms reacts to the cycle and so again the propagation mechanism differs from ours. There also is no return to specialization in their economy. Baxter and King (1990) study a thick market externality that is similar in effect to ours, but that arises in a competitive environment and is not related to entry and exit of firms.

The rest of the paper is organized as follows. The economy is described in Section II and the effects of increasing returns to scale and specialization for various degrees of market power are compared in a series of computational experiments in Section III. Section IV illustrates the ability of entry and exit in the presence of increasing returns to specialization to account for failures of Solow residual invariance to government spending. Section V begins with the derivation of the appropriate measures of residuals implied by the theoretical economics and a characterization of the bias inherent in using fluctuations as measures of technology shocks. We then examine the economy's quantitative cyclical properties when technology shocks exhibit the time series properties of the implied residuals in U.S. Data. Section VI concludes.

II. The Economy

We consider an economy which incorporates imperfectly competitive markets, increasing returns to both scale and specialization, and endogenous entry and exit of firms over the business cycle. The following parametric representation of the economy is used in a series of computational experiments to investigate the role of these factors in determining the economy's cyclical properties.

Technologies

There is a single final good which is used for both consumption and investment and a continuum of potential intermediate goods which are used solely in production of the final good. Let N_t denote the measure of intermediate goods produced at time t. Each intermediate good is produced by a monopolist using an increasing returns to scale technology: $\forall t$, $\forall i \in [0, N_t]$,

$$m_{it} = z_t[k_{it}^{\alpha} h_{it}^{1-\alpha}]^{\gamma} - \phi, \tag{1}$$

where $\alpha \in [0,1]$, $\phi > 0$, and $\gamma \geq 1$. Here k_{it} and h_{it} denote respectively the quantities of capital and labor employed in production of intermediate good i, and z_t is a technology shock affecting the technologies for producing all intermediate goods symmetrically. The technology shock, z_t, evolves according to:

$$\ln z_t = \omega \ln z_{t-1} + \epsilon_t \tag{2}$$

where ϵ_t is a mean zero, i.i.d. process with variance σ_{ϵ}^2. The specification given by (1) allows for two sources of increasing returns to scale: fixed costs given by $\phi > 0$ and increasing returns in variable production given by $\gamma > 1$.

The technology for producing the final good depends upon both the quantity and measure of intermediate goods employed: $\forall t$,

$$y_t = F(N_t, m_{it} : i \in [0, N_t]). \tag{3}$$

This technology may exhibit either constant or increasing returns in the measure of intermediate goods:

$$y_t = N_t{}^{\lambda}\left[\int_0^{N_t} m_{it}^{\rho}\, di\right]^{\frac{1}{\rho}} \qquad 0 < \rho < 1, \tag{4.1}$$

where these returns are governed by λ. This can be seen as follows. Suppose that an equal quantity of each intermediate good is employed (i.e. $m_{it} = m_t \; \forall i \in [0, N_t]$). Then the final goods technology can be written as

$$y_t = N_t{}^{\lambda+1/\rho} m_t. \tag{4.2}$$

We define returns to specialization as the change in y_t for a given change in the measure of products, N_t, holding quantity employed of each product, m_t, constant. Two cases are considered: $\lambda = 0$ in which case the degree of return to specialization is $1/\rho > 1$; and $\lambda = 1 - 1/\rho$, in which case there are constant returns to specialization. In the increasing returns to specialization case, the technology corresponds to that of Ethier (1982).

Capital is produced by means of a standard intertemporal technology. The law of motion for the aggregate capital stock, K, is given by

$$K_{t+1} = (1-\delta)K_t + X_t \tag{5}$$

where δ is the depreciation rate and investment, X_t, is foregone consumption of the final good at time t.

Preferences

A representative household has period preferences over consumption of the final good and leisure given by

$$U(c_t, h_t) = \ln c_t + \eta \ln(L - h_t) \tag{6}$$

where L is the endowment of leisure each period and h_t is the time spent working. The lifetime utility function of the representative household is then given by

$$E_o\left[\sum_{t=0}^{\infty} \beta^t U(c_t, h_t)\right]$$

where $0 < \beta < 1$ is the discount factor.

The measure of households is normalized to one. Therefore, letting K and H denote the aggregate capital stock and labor supply and letting k and h denote individual household capital stock and labor supply, feasibility requires

$$K_t = k_t = \int_0^{N_t} k_{it}\ di \tag{7}$$

and

$$H_t = h_t = \int_0^{N_t} h_{it}\ di. \tag{8}$$

Market Arrangements

Consumers and final good producers behave competitively in all markets. Consumers own the capital stock and rent both it and labor services to intermediate goods producers in competitive factor markets. Intermediate goods producers are monopolistically competitive and there is free entry into the industry.

Equilibrium

We consider economic fluctuations in a symmetric recursive equilibrium. First we solve the static profit maximization problems of both the final and intermediate goods producers and derive the equilibrium process for the number of firms as a function of the aggregate state and decision variables. We then solve the utility maximization problem of a representative household which takes as given factor prices and the number of firms.

Firms

Profit maximization by final good producers implies the following cost function:

$$C^Y(p, y) = yN^{-\lambda}\left[\int_0^{N} p_i^{\frac{\rho}{\rho-1}}\, di\right]^{\frac{\rho-1}{\rho}} \tag{9}$$

where p_i is the price of intermediate good i (time subscripts have been suppressed). The conditional demand function for intermediate good j, then, is given by

$$m_j(p, y) = (yN^{-\lambda})\frac{p_j^{\frac{1}{\rho-1}}}{\left[\int_0^N p_i^{\frac{\rho}{\rho-1}}\, di\right]^{\frac{1}{\rho}}} \tag{10}$$

Note that this demand function is characterized by a constant elasticity of demand,

$\mu = 1/(\rho - 1)$, which is independent of λ.

A representative intermediate good producer (the subscript j is suppressed) faces the following profit maximization problem in each period:

$$\max_{p} pm(p, y) - C^M(w, r, m(p, y))$$

where,

$$C^M(w, r, m; z) = Ar^{\alpha} w^{1-\alpha} \left[\frac{m + \phi}{z}\right]^{\frac{1}{\gamma}} \tag{11}$$

and

$$A \equiv \left(\frac{1-\alpha}{\alpha}\right)^{\alpha} + \left(\frac{1-\alpha}{\alpha}\right)^{\alpha-1}.$$

The conditional demand functions for labor and capital are given by

$$h(w, r, m; z) = \left(\frac{r}{w}\right)^{\alpha} \left(\frac{1-\alpha}{\alpha}\right)^{\alpha} \left[\frac{m + \phi}{z}\right]^{\frac{1}{\gamma}} \tag{12.1}$$

$$k(w, r, m; z) = \left(\frac{r}{w}\right)^{\alpha-1} \left(\frac{1-\alpha}{\alpha}\right)^{\alpha-1} \left[\frac{m + \phi}{z}\right]^{\frac{1}{\gamma}}. \tag{12.2}$$

Since there are a continuum of intermediate good producers, each producer takes the term in the denominator of the demand function given by (10) as given. Therefore, solution of the profit maximization problem yields the familiar constant mark-up pricing rule:

$$p = \left(\frac{1}{\rho}\right) \left[\frac{\partial C^M(w, r, m; z)}{\partial m}\right] \tag{13}$$

In equilibrium, the price of the final good must equal its unit cost. Normalizing the price of the final good to 1, this condition is written:

$$1 = N^{-\lambda} \left[\int_0^N p_i^{\frac{\rho}{\rho-1}} di\right]^{\frac{\rho-1}{\rho}}. \tag{14}$$

In a symmetric equilibrium prices and quantities of intermediate goods and factor employment per intermediate good producer are equal across firms (i.e. $p_i = p$, $m_i = m$, $k_i = K/N$, and $h_i = H/N$ $\forall i \in [0, N]$). The solutions to the firms' static maximization problems together with feasibility and factor market clearing yield the following conditions that must hold period by period in such an equilibrium:

$$p = N^{(\lambda + 1/\rho - 1)} \tag{15.1}$$

$$\left[\frac{m+\phi}{z}\right]^{\frac{1}{\gamma}} = \frac{K^{\alpha}H^{1-\alpha}}{N} \tag{15.2}$$

$$K/N = \left(\frac{w}{r}\right)^{1-\alpha}\left(\frac{\alpha}{1-\alpha}\right)^{1-\alpha}\left[\frac{m+\phi}{z}\right]^{\frac{1}{\gamma}} \tag{15.3}$$

$$p = \left(\frac{A}{z\gamma\rho}\right)r^{\alpha}w^{1-\alpha}\left[\frac{m+\phi}{z}\right]^{\frac{1-\gamma}{\gamma}} \tag{15.4}$$

$$pm - Ar^{\alpha}w^{1-\alpha}\left[\frac{m+\phi}{z}\right]^{\frac{1}{\gamma}} = 0. \tag{15.5}$$

Equation (15.1) is the symmetric equilibrium equivalent of (14). Equation (15.2) represents technological feasibility in production of intermediate goods. Equation (15.3) represents capital market clearing. Equation (15.4) is the mark-up pricing equation given by (13). Equation (15.5) represents the free entry condition characterized by zero profits in the intermediate good sector.

This system of equations is used to derive expressions for equilibrium factor prices and the measure of intermediate goods as functions of aggregate capital, employment, and the technology shock, all of which are taken as given by households.

$$w(K,H,z) = (1-\alpha)\Lambda z^{\frac{1+\rho\lambda}{\rho\gamma}}\left[\frac{(K^{\alpha}H^{1-\alpha})^{(\lambda+1/\rho)}}{H}\right] \tag{16.1}$$

$$r(K,H,z) = \alpha\Lambda z^{\frac{1+\rho\lambda}{\rho\gamma}}\left[\frac{(K^{\alpha}H^{1-\alpha})^{(\lambda+1/\rho)}}{K}\right] \tag{16.2}$$

$$N(K,H,z) = \left[\frac{z(1-\rho\gamma)}{\phi}\right]^{\frac{1}{\gamma}}(K^{\alpha}H^{1-\alpha}) \tag{16.3}$$

where

$$\Lambda = \rho\gamma\left[\frac{1-\rho\gamma}{\phi}\right]^{\frac{\lambda+1/\rho-\gamma}{\gamma}}.$$

Note from equation (16.3), that parameters must be restricted such that $\gamma < 1/\rho$ to guarantee a positive measure of intermediates. This condition simply reflects the requirement that for a given degree of increasing returns to scale, firms must have sufficient market power to price so as to earn non-negative profits.

Also note that equation (16.3) and the technology for intermediate good production given by equation (1) imply that the quantity of each intermediate good produced is constant and independent of the technology shock, z:

$$m = \frac{\rho\gamma\phi}{1-\rho\gamma}. \tag{17}$$

Therefore, a technology shock will affect equilibrium variables only through its effect on factor demands and the equilibrium *measure* of intermediate goods.

Households

A household chooses individual consumption, leisure, and investment to maximize expected discounted lifetime utility taking aggregate variables, factor prices ((16.1) and (16.2)), and the number of firms (16.3) as given. A representative household's optimization problem can be written recursively as:

$$P1 \qquad V(k,K,z) = \max_{c,h,x,k'} \{U(c,h) + \beta EV(k',K',z'|k,K,z)\}$$

subject to:

$$c + x = w(K,H,z)h + r(K,H,z)k$$

$$k' = (1-\delta)k + x$$

$$K' = (1-\delta)K + X$$

$$C = C(K,z)$$

$$H = H(K,z)$$

$$X = X(K,z)$$

$$K' = K'(K,z)$$

$$\ln z' = \omega \ln z + \epsilon$$

A symmetric recursive equilibrium is defined as a collection of individual decision rules, $\{c, h, x, k'\}$, aggregate decision rules, $\{C, H, X, K'\}$, and a value function, V(k,K,z), such that:

i. $\{c, h, x, k'\}$ solve *P1* given $\{C, H, X, K'\}$.

ii. a. $C(K, z) = c(K, K, z)$

b. $H(K, z) = h(K, K, z)$

c. $X(K, z) = x(K, K, z)$

d. $K'(K, z) = k'(K, K, z)$

Calculation of Equilibrium

We apply the procedures for computing approximations to the equilibrium stochastic process of a homogeneous agent economy as described in Hansen and Prescott (1991). The first step is to compute the economy's deterministic steady-state. We then quadratically approximate P1 in a neighborhood of this allocation and solve the resulting linear-quadratic dynamic programming problem using standard methods, imposing equilibrium conditions (ii.a)-(ii.d) at each iteration.

We first derive the deterministic steady-state equilibrium for this economy. The household's problem can be written as a problem in the choice variables h and k' alone by substituting in the two individual constraints into the objective function for c:

$$c = w(K, H, z)h + r(K, H, z)k - k' + (1 - \delta)k \tag{18}$$

The first-order conditions are written:

$$\frac{w(K, H, z)}{c} = \frac{\eta}{L - h} \tag{19.1}$$

$$\frac{1}{c} = \beta E\left[\frac{\partial V(k', K', z|k, K, z)}{\partial k'}\right] \tag{19.2}$$

where c is given by Equation (18). Application of the Benveniste and Scheinkman (1979) formula yields,

$$\frac{\partial V(k, K, z)}{\partial k} = \frac{r(K, H, z) + 1 - \delta}{c}.$$

Using (19.2), we can write an expression for the rental rate of capital in the deterministic steady-state,

$$\bar{r} = 1/\beta + \delta - 1. \tag{20.1}$$

Let $\bar{z}$ be the unconditional mean of the technology shock. Then combining the remaining first-order condition, (19.1), with the equilibrium equations in (16) gives the remaining deterministic steady-state equilibrium variables:

$$\bar{w} = \bar{r}\left(\frac{1-\alpha}{\alpha}\right)\left(\frac{\bar{K}}{\bar{H}}\right) \tag{20.2}$$

$$\bar{H} = \bar{h} = \frac{(1-\alpha)L\bar{r}}{(1+\eta-\alpha)\bar{r} - \alpha\eta\delta} \tag{20.3}$$

$$\bar{K} = \bar{k} = \left[\alpha \Lambda z^{\frac{1+\rho\lambda}{\rho\gamma}}\right]^{\frac{-\rho}{\upsilon}} \bar{r}^{\frac{\rho}{\upsilon}} \bar{H}^{\frac{(1+\rho\lambda)(\alpha-1)}{\upsilon}} \tag{20.4}$$

$$\bar{N} = \left[\frac{\bar{z}(1-\rho\gamma)}{\phi}\right]^{\frac{1}{\gamma}} (\bar{K}^{\alpha}\bar{H}^{1-\alpha}) \tag{20.4}$$

$$\bar{m} = \bar{z}\bar{N}^{-\gamma}(\bar{K}^{\alpha}\bar{H}^{1-\alpha})^{\gamma} - \phi \tag{20.5}$$

$$\bar{p} = \bar{N}^{(\lambda+1/\rho-1)} \tag{20.6}$$

$$\bar{y} = \bar{N}^{(\lambda+1/\rho)}\bar{m} \tag{20.7}$$

$$\bar{C} = \bar{c} = \bar{y} - \delta\bar{K} \tag{20.8}$$

where

$$\upsilon = \rho(\alpha\lambda - 1) + \alpha.$$

As discussed above, the objective function in problem P1 is quadratically approximated around this steady-state and decision rules are derived. The decision rule, together with the state laws of motion given by (2) and (5) can then be used to compute realizations of the equilibrium stochastic processes.

III. Propagation: Cyclical Properties for Fixed Impulse Dynamics

We now examine the effects of market power, increasing returns to scale, and increasing returns to specialization on equilibrium aggregate fluctuations in the presence of endogenous entry and exit of intermediate goods producers. The parameters ρ and γ which govern the markup ratio and returns to scale in intermediate goods production respectively are varied, and the effects on the cyclical properties of aggregates are characterized. We do not attempt to calibrate the models to the real economy. Rather, we analyze the effects of returns to scale and specialization on the propagation mechanisms in the theoretical economies for a given sequence of technology shocks. The properties of these economies are also compared to a 'standard' competitive benchmark RBC economy in which only final goods are produced using capital and labor.

Gross national product in this economy, denoted G, is defined as the sum of final and intermediate goods output less the value of intermediate goods used in production of the final good:

$$G = y + pN(m + \phi) - pNm, \tag{21.1}$$

From equations (14.2) and (15.1), G can be written in terms of the measure of firms, N and gross per firm output of intermediate goods, $m + \phi$:

$$G = N^{\lambda+1/\rho}(m + \phi) \tag{21.2}$$

or taking logs:

$$\ln G = (\lambda + 1/\rho)\ln N + \ln(m + \phi). \tag{21.3}$$

As noted by equation (17), output per firm is constant over the business cycle and fluctuations in G are driven by fluctuations in N. In the constant returns to specialization case when $\lambda = 1 - 1/\rho$, it can be seen from equation (21.3) that G and N will exhibit the same percentage variability. However, in the increasing returns to specialization case when $\lambda = 0$, the percentage variation in G will be approximately $1/\rho(> 1)$ times the percentage variation in N. That is, increasing returns to specialization introduce a 'multiplier' in the sense that for a given change in N, G changes more the greater is $1/\rho$. This multiplier arises from what may be thought of as an endogenous response of the gross productivity of capital and labor that occurs when an exogenous technology shock causes the measure of intermediate goods to change. The following experiments quantify this effect for differing degrees of returns to specialization and scale.

To run an experiment, it is necessary to fully parameterize the economy. We take several parameters from the RBC literature. Specifically, we set the subjective rate of time preference, $\beta = .99$; the share parameter in the period utility function, $\eta = 2$; the intermediate goods technology parameter, $\alpha = .36$; and the rate of capital depreciation, $\delta = .025$ to correspond to the parameters used in Prescott (1986). We also set the period time endowment, $L = 1$, and the fixed cost parameter, $\phi = 1$.

The technology shock process (2) contains two parameters, ω and σ_ϵ. Typically, RBC studies have obtained estimates of these parameters from autoregressions using the standard Solow residual,

$$\ln z = \ln G - (1 - \Omega) \ln K - \Omega \ln H, \tag{22}$$

where Ω is labor's share in GNP. We again use Prescott's (1986) value, and set $\Omega = .64$. While the Solow residual is an appropriate measure of gross factor productivity under the assumptions of perfect competition and constant returns to scale it will, as noted earlier, give biased measures of true shifts in the aggregate technology under market power and increasing returns to scale. The appropriate residuals for the economies studied here are discussed in detail in Section V. For now we are interested only in comparisons across economies for a given sequence of shocks.

The magnitude and first order autocorrelation of Hodrick-Prescott (1980) detrended residuals were obtained by estimating (2) using quarterly data on gross domestic product, total employment, and the gross capital stock (see the notes to Table 5 for details on the data). Our estimate of ω is .71 with a standard error of .071 and our point estimate of σ_ϵ is .0068. Basing the technology shock process on properties of the Solow residual and using parameters consistent with those of Prescott (1986) has the advantage that our benchmark competitive model corresponds quantitatively to a standard RBC model.

Figures 2 and 3 depict dynamic equilibrium responses of aggregates to a one-time technology shock of one standard deviation under constant and increasing returns to specialization respectively. In each figure, the curves marked G denote the response of GNP, those marked N denote the response of the measure of firms, those marked K denote the response of the aggregate capital stock, and those marked H denote the response of aggregate employment. Computational experiments can reinforce the relationships suggested by the impulse responses. An experiment consists of computation of the economy's equilibrium stochastic process for 5000 periods. A single 5000 period realization of (2) is drawn using the estimates of ω and σ_ϵ given above and is used in all experiments. Cyclical properties of the economies are summarized by the sample standard deviations of gross national product, G; consumption, C; investment, X; the aggregate capital stock, K; employment, H; and the measure of firms, N. These sample moments are interpreted as estimates of the population moments, which cannot be derived analytically. The outcomes of these experiments are summarized in Tables 1-4.

Consider first economies with constant returns to specialization. Figure 2 contains the responses of aggregates to a technology shock for three cases plus, in the lower right panel, the responses of aggregates for a benchmark competitive economy. In response to the (positive) shock, firms enter causing the measure of intermediate goods to rise. This response of the equilibrium measure of intermediate products translates into responses of output and other aggregates. The one-to-one correspondence suggested earlier between σ_N and σ_G is clearly apparent for all three constant return economies.

Two other points are illustrated by Figure 2. First, when $\gamma = 1$, the aggregates of the constant returns to specialization economy exhibit *exactly* the same percentage response to a technology shock as their competitive counterparts independent of the size of ρ. Hence, market power in itself has no implication for the equilibrium effect of a technology shock. Second, as the degree of internal increasing returns to scale (γ) increases, the percentage responses of aggregates to a technology shock are dampened. This effect can be made explicit by writing G as a function of the number of intermediate goods, N, the technology shock, z, and a measure of total factor inputs, $K^\alpha H^{1-\alpha}$:

$$G = N^{\lambda + \frac{1}{\rho} - \gamma} z (K^\alpha H^{1-\alpha})^\gamma. \tag{23}$$

In the economy with internal returns to scale but constant returns to specialization, $\lambda = 1 - 1/\rho$ and $\gamma > 1$. Using (16.3) it can be seen that G fluctuates in proportion to $z^{\frac{1}{\gamma}}(K^\alpha H^{1-\alpha})$. Thus the elasticity of G with respect to the technology shock, z, is inversely proportional to the degree of internal increasing returns, and as γ increases, the effects of a given technology shock on aggregates are dampened.

Tables 1 and 2 contain the percent sample standard deviations of aggregates for constant returns to specialization economies computed from a single simulation of 5000 periods in length. The rightmost column of Table 1 contains sample moments for the benchmark competitive economy. In Table 1 economies in which the only increasing returns arise from fixed costs in the production of intermediate goods ($\gamma = 1$) are considered. As suggested by Figure 2, the cyclical properties of these economies are *identical* to those of the competitive economy independent of the level of ρ. Thus the introduction of market power and entry and exit in this manner in no way affects the volatility of aggregates generated by a given sequence of technology shocks. Though this is not shown in Table 1, which contains only sample standard deviations, market power and entry and exit under constant returns to specialization also have no effect on either the contemporaneous comovements of aggregates, or their autocorrelation.

In Table 2 we consider economies with varying degrees of returns to scale in the production of intermediate goods. These results hold independent of ρ. Again, as suggested by Figure 2, as γ increases the volatilities of all aggregates in response to technology shocks are dampened. The degree of returns in intermediate goods production also has no affect on the comovements or autocorrelations of any of the aggregates studied.

Now consider the introduction of increasing returns to specialization. Figure 3 contains the responses of aggregates to a technology shock for three cases. All three panels illustrate the endogenous productivity response discussed earlier. G exhibits a larger response than does N and the difference in the responses is increasing in the degree of increasing returns to specialization, $1/\rho$. For this reason, in contrast to economies with constant returns to specialization, when $\gamma = 1$ the economies exhibits stronger responses of aggregates than does the competitive economy. These responses are, however, again dampened as γ increases. In this case, using (23) and (16.3), it can be seen that G fluctuates in proportion to $z^{\frac{1}{\gamma\rho}}(K^{\alpha}H^{1-\alpha})^{\frac{1}{\rho}}$. Since $\rho < 1$ and $\rho\gamma < 1$, the elasticity of output with respect to *both* the technology shock *and* total factor inputs are greater than unity, and inversely proportional to ρ. This illustrates the endogenous response in total factor productivity to a technology shock which is quantitatively proportional to $1/\rho$. As before, the elasticity of output with respect to a technology shock is decreasing in γ. Nevertheless, with $\rho = .7$ and $\gamma = 1.3$, the response of aggregates to a shock are significantly stronger than those exhibited by the competitive benchmark economy.

These relationships are also apparent in Tables 3 and 4, which report the sample standard deviations of aggregates for economies with increasing returns to specialization. Table 3 illustrates the effect of ρ on the volatilities of aggregates for $\gamma = 1$. A decrease in ρ is associated with an increase in both market power, and the degree of increasing returns to specialization. Clearly, as returns to specialization increase, the volatility of aggregates all increase as well. For $\rho = .7$ the economy exhibits roughly twice as much volatility as its competitive and constant returns to specialization counterparts. In Table 4, the role of γ under increasing returns to specialization is analyzed. For fixed ρ, increases in γ continue to dampen the volatilities of all aggregates. The multiplier associated with the endogenous factor productivity response, however, is unaffected by γ.

Now consider the bias inherent in using the Solow residual (22) as a measure of the true technology shock, z in these economies. Figure 2B contains the dynamic responses of both the technology shock (labelled 'Z') and the Solow residual (labelled 'SR') for the same economies as depicted in Figure 2. The lower right panel again contains the dynamic response of the competitive economy. Since the Solow residual is an appropriate measure of technology shocks for this economy, it is not surprising that the paths of the two variables correspond exactly. The top two panels illustrate that monopolistic competition in itself has no effect on this relationship. Regardless of the degree of market power, the Solow residual remains an exact measure of the technology shock. With internal increasing returns, however, this correspondence is broken. As the lower left panel illustrates, the Solow residual *underestimates* the magnitude of the technology shock, although the two remain perfectly correlated. This bias arises as aggregate variables fluctuate in proportion to $z^{\frac{1}{\gamma}}$. Thus the extent to which the Solow residual understates technology shocks increases with the degree of internal returns to scale.

Figure 3B contains the analogous responses for the economies with increasing returns to specialization. Note that in all cases the Solow residual *overestimates* the magnitude of the technology shock. This is due to the endogenous response of total factor productivity, which is captured by the Solow residual. Also note that the two measures are no longer perfectly correlated. For large enough increasing returns to specialization, the Solow residual increases for two periods in response to a technology shock. The first period response is due mainly to the direct effect of the technology shock, while that in the second period results from the effect of capital accumulation, which takes one period to occur. The lower left panel illustrates that in the presence of both types of increasing returns the Solow residual may understate the initial shock, and then record a further increase in the second period, when the true technology shock is in fact abating.

The main finding of these experiments is that increasing returns to specialization, coupled with entry and exit of firms over the business cycle can drastically increase the magnitude of aggregate fluctuations emanating from a given sequence of technology shocks, while internal returns to scale will tend to dampen these fluctuations. The results are driven primarily by increasing returns to specialization and not by market power and entry and exit in themselves. Also, if the Solow residual is used as a measure of technology shocks in these economies, it will tend to understate the magnitude of these shocks in the case of internal increasing returns and overstate both the magnitude and persistence of these shocks in the case of external returns to specialization.

IV. Invariance of the Solow Residual: Government Spending Shocks

In Figures 2B and 3B it was shown that in the presence of increasing returns to specialization the Solow residual will overstate technology shocks because of an endogenous response of total factor productivity. It is now demonstrated that these endogenous productivity fluctuations can account for failures of Solow residual invariance to government spending shocks, and implicitly to other types of aggregate demand shocks. Empirical evidence for such failures of invariance has been documented by Evans (1992), Finn (1992), Hall (1989), and others.

The economy described in Section II is modified to incorporate a government spending shock and this shock is shown to produce endogenous procyclical movements in the Solow residual under increasing returns to specialization. Fluctuations in government spending are modeled in the simplest manner possible. The government consumes a time-varying portion of the final good each period and finances its consumption through a lump-sum income tax. For simplicity, we assume that government consumption does not enter the representative consumer's utility function. This assumption makes no difference for our qualitative results. The government consumes d_t units of the final good in period t, where $\forall t$:

$$\ln d_t = \nu \ln d_{t-1} + \theta_t, \tag{24}$$

and θ_t is an iid random variable, distributed normally with mean 0 and variance σ_θ^2. The government finances its consumption each period by levying a lump sum tax, τ_t, to balance its budget: $\forall t$

$$d_t = \tau_t. \tag{25}$$

Given that government spending is financed by nondistorting taxation, it has no effect on the producer equilibrium conditions given by (15.1)-(15.5), the equilibrium factor prices, (16.1) and (16.2), or the equilibrium measure of firms given by (16.3). The representative consumer's dynamic problem, $P1$, changes only through the addition of another exogenous state variable, d and through the budget constraint, which becomes:

$$c + x = w(K, H, z, d)h + r(K, H, z, d)k - \tau. \tag{26}$$

We again focus on a symmetric recursive equilibrium, and solve the model as described in Section II.

Steady-state government expenditure is chosen to reflect the average share of government purchases in quarterly U.S. GNP. Using real (base 1982) data from Citibase, the average share for the period 1960.1-1989.4 is .2097. The magnitude and first order autocorrelation of government spending shocks were obtained by estimating (25) using this data detrended by the Hodrick-Prescott filter. Our estimate of ν is .86 with a standard error of .044 and our point estimate of σ_θ is .0089.

Figures 4 and 5 depict the dynamic responses of aggregates to a one time government spending shock under constant and increasing returns to specialization respectively. In each figure, the lower right panel describes the path of the government spending shock. As in Figures 2B and 3B the Solow residual is labelled 'SR'. Figure 4 illustrates that under constant returns to specialization, the Solow residual is invariant to government spending shocks independent of the degree of market power and the degree of increasing returns to scale. This result is not surprising as the economy with constant returns to specialization does not exhibit an endogenous productivity response.

Under increasing returns to specialization, however, a shock to government spending causes a procyclical movement in the Solow residual. This effect arises because the Solow residual measures all of the fluctuation in GNP not attributable to changes in capital and labor input weighted by $1 - \Omega$ and Ω respectively. Due to the increasing returns to specialization multiplier, a positive government spending shock results in a stronger increase in G than can be accounted for by the increase in H coupled with the decrease in K. Thus the Solow residual increases and closely tracks the path of government spending. This result arises solely due to the endogenous productivity response that occurs under increasing returns to specialization.

This example illustrates that in economies with entry and exit and increasing returns to specialization, the Solow residual will generally fail to be invariant to an aggregate demand shock of any type. This issue is, however, entirely separate from that of the extent to which technology shocks account for cycles, since the Solow residual is not an appropriate measure of technology shocks even in the absence of demand shocks. We now turn to the issue of the effects of market power, increasing returns to scale, and increasing returns to specialization on the appropriate technology shock measure implied by these theoretical environments.

V. Fluctuations with Implied Technology Shock Measures

The experiments of Section III illustrate the effects of introducing market power and increasing returns both to scale and specialization on the propagation of a given sequence of technology shocks. The sequence of technology shocks used in those experiments exhibits the time series properties of the Solow residual, a clearly inappropriate measure of technology shocks in the presence of these types of increasing returns, as was shown in Figures 2B and 3B. In this section, we derive the appropriate residual measures implied by the theoretical economy and use them to estimate technology shocks for the U.S. economy.

By comparing these measures to the Solow residual we obtain a rough estimate of the bias inherent in using the the latter as a measure of technology shocks. Then, parameterizing the technology shock process in the model to reflect the time series properties of these adjusted residual measures, we compare the cyclical properties of economies with perfect competition, imperfect competition, increasing returns to scale but constant returns to specialization, and imperfect competition with increasing returns to both scale and specialization. In this way we assess the net effect of increasing returns to specialization on the share of aggregate fluctuations accounted for by technology shocks.

Implied Residual Measures

Substituting the intermediate goods technology (1) and the equilibrium measure of intermediate goods given by (16.3) into equation (21.2) gives GNP as a function of the aggregate capital stock, aggregate employment, and the technology shock:

$$G = \Gamma z^{\frac{\lambda+1/\rho}{\gamma}} (K^{\alpha} H^{1-\alpha})^{\lambda+1/\rho} \tag{27}$$

where

$$\Gamma = \left[\frac{1-\rho\gamma}{\phi}\right]^{\frac{\lambda+1/\rho-\gamma}{\gamma}}.$$

Taking logs of both sides gives a measure of the residual for this economy:

$$\ln z = \frac{\gamma}{\lambda+1/\rho} \ln G - \alpha\gamma \ln K - (1-\alpha)\gamma \ln H - \Psi,$$

where

$$\Psi = \frac{\gamma}{\lambda+1/\rho} \ln \Gamma.$$

The residual can also be expressed in (approximate) growth rates:

$$\Delta \ln z = \frac{\gamma}{\lambda+1/\rho} \Delta \ln G - \alpha\gamma \Delta \ln K - (1-\alpha)\gamma \Delta \ln H.$$

Now $\alpha\rho\gamma$ and $(1-\alpha)\rho\gamma$ are capital's and labor's GNP shares respectively. This can be seen as follows. A profit maximizing intermediate good producer will employ capital and labor such that:

$$w = (1 - 1/\mu) VMPL$$

$$r = (1 - 1/\mu)VMPK,$$

where $VMPL$ and $VMPK$ are the marginal value products of labor and capital respectively and $\mu = 1/(\rho - 1)$ is the elasticity of demand for intermediate goods. Thus,

$$w = \rho(1-\alpha)\gamma pz(K^\alpha H^{1-\alpha})^\gamma H^{-1}$$

$$r = \rho\alpha\gamma pz(K^\alpha H^{1-\alpha})^\gamma K^{-1},$$

or

$$\frac{wH}{pN(m+\phi)} = \rho(1-\alpha)\gamma$$
$$\frac{rK}{pN(m+\phi)} = \rho\alpha\gamma.$$

But, in equilibrium, $pN(m+\phi) = G$. Therefore $\alpha\rho\gamma$ represents the share of capital's compensation in GNP, and $(1-\alpha)\rho\gamma$ is labor's share. So, letting Ω be the (measurable) labor share, the residuals can be written:

$$\ln z = \frac{\gamma}{\lambda + 1/\rho}\ln G - \frac{(\rho\gamma - \Omega)}{\rho}\ln K - \frac{\Omega}{\rho}\ln H - \Psi \tag{28}$$

and

$$\Delta \ln z = \frac{\gamma}{\lambda + 1/\rho}\Delta \ln G - \frac{(\rho\gamma - \Omega)}{\rho}\Delta \ln K - \frac{\Omega}{\rho}\Delta \ln H. \tag{28$'$}$$

Equations (28) and (28$'$) can be used to obtain measures of technology shocks for the U.S. economy. It is difficult to be precise about the relationships between these measures and the Solow residual. This is because the relationship between (28) and (22) depends not only on the parameters ρ, γ, λ, and Ω, but also on the cross correlation properties of the measures chosen for G, H, and K. We proceed as follows: Using our sample of U.S. quarterly observations for G, H, and K, for each choice of parameters ρ, γ, and λ we calculate a series of residuals using (28). This sequence is then detrended using the Hodrick-Prescott filter with smoothing parameter 1600, and the standard deviations of the detrended residual measures are recorded in Tables 6 and 7. In each table, the case where $\rho = \gamma = 1$ contains the standard deviation of the Solow residual.

Tables 6 and 7 suggest that the measured variance of technology shocks is generally decreasing in the degree of increasing returns to specialization and increasing in the degree of internal returns to scale. These results constitute a rough characterization of the bias inherent in using fluctuations in the Solow residual as measures of technology shocks. Hall (1989) has argued that when this bias is taken into account, the variability in technology shocks may be much smaller than suggested by variations in the Solow residual. Clearly, given the cyclical properties of U.S. data, imperfect competition and increasing returns to specialization may cause the variance of the Solow residual to significantly overstate the variance of technology shocks. Internal increasing returns to scale will, however, mitigate this effect, and may (in the absence of increasing returns to specialization) cause the variance of the Solow residual to *understate* the variance of technology shocks. These results do not depend on our modeling of residuals as fluctuations about a Hodrick-Prescott trend. In Tables 6A and 7A the same exercise is carried out using residual growth rates (from (28′)) and the same relationships are observed.

Cyclical Properties of the Theoretical Economies

We now analyze the cyclical properties of the theoretical economies with the parameters ω and σ_ϵ estimated from equation (2) using the appropriate residual measure applied to U.S. data in place of the Solow residual. As this measure depends on ρ and γ it is necessary to choose values for these parameters and hold them constant across economies. We take our values from Morrison (1990), in which markups and returns to scale coefficients for two digit U.S. manufacturing industries are estimated for the period 1960-86. We set ρ equal to Morrison's estimate of the markup ratio for total manufacturing, the broadest aggregate she considers. Similarly we set γ equal to her estimate of the returns to scale coefficient for the same category. These values are $\rho = .8354$ (Table 2, p.25) and $\gamma = 1.1416$ (Table 3, p.29). With these values for ρ and γ, the estimates for the persistence parameter of the technology shock process are $\omega = .70$ for constant returns to specialization and $\omega = .64$ for increasing returns, both with standard errors of .066. Point estimates for the standard deviation of innovations are $\sigma_\epsilon = .0076$ for constant returns to specialization and $\sigma_\epsilon = .0063$ for increasing returns. All other parameters remain at the values used in the experiments of Section III. Since the focus here is on the effects of technology shocks, we abstract entirely from shocks to government spending.

As in the computational experiments of Section III, our purpose is to make comparisons across economies, rather than to match the cyclical properties of detrended U.S. data. We compare our imperfectly competitive economies to a benchmark competitive model. Of particular interest are the differences in the variability and autocorrelation of technology shocks across economies and the combined quantitative effect of these differences in impulse dynamics on the propagation of shocks under varying degrees of returns to scale and specialization. Tables 8-10 summarize the cyclical properties of the three theoretical economies. The first rows of Tables 8 and 10 contain the variance and autocorrelation of the implied residual for each economy.

Under constant returns to specialization, the implied residual is indeed more variable than the Solow residual, and in this sense, if this model characterized the true nature of the U.S. economy, the variance of the Solow residual would *understate* the variance of technology shocks. Given these impulse dynamics, this economy exhibits very similar cyclical properties to that of the competitive benchmark. The volatilities of G and H are almost identical across the two economies, although C, X, and K are all somewhat more volatile in the imperfectly competitive economy. The economies also exhibit very similar contemporaneous correlations of aggregates with output and similar first order autocorrelations. One interesting difference is that consumption appears to be significantly more autocorrelated in the constant returns to specialization economy than in the competitive benchmark. In general, these results may be interpreted as suggesting robustness of the predictions of perfectly competitive real business cycle models. To the extent that technology shocks account for a significant share of aggregate fluctuations under the assumptions of perfect competition and constant returns to scale, they continue do so under monopolistic competition and internal increasing returns to scale. In addition, the variability of technology shocks may be larger than suggested by variation in the Solow residual.

Under increasing returns to specialization, the implied residual is approximately 15% less variable than the Solow residual. The technology shocks patterned on this residual are also somewhat less persistent than those of the competitive economy. Nevertheless, these 'smaller' technology shocks can account for more fluctuation in aggregates than suggested by the competitive economy. All aggregates except consumption experience greater fluctuation in this economy than in the competitive benchmark, while the contemporaneous correlations and first order autocorrelations are again quite similar across the two economies. In particular aggregate output, G, fluctuates approximately 8% more in this economy than in the competitive economy, in spite of the fact that technology shocks are smaller and less persistent. Thus, to the extent that productivity shocks can be seen to account for a substantial share of aggregate fluctuations under the assumptions of perfect competition, this share is *increased* when the propagation mechanism and measure of technology shocks are both modified to allow for imperfect competition and increasing returns to scale and specialization.

VI. Conclusions

This paper has examined an RBC model which incorporates cyclical entry and exit of monopolistically competitive firms, internal returns to scale, and external returns to specialization. Returns to specialization are interpreted as a thick market effect fundamentally linked to the economy's market structure. These features of the environment have critical implications both for the implied measurement and propagation of technology shocks. Market power and endogenous entry and exit in themselves have little effect on the propagation of such a shock. In contrast, internal returns to scale dampen the effect of these shocks while external returns to specialization produce a strong multiplier which accentuates their effects. The multiplier arises as fluctuations in the number of firms over the business cycle cause endogenous fluctuations in the productivity of intermediate inputs. These endogenous productivity fluctuations cause the Solow residual to mismeasure technology shocks, and can account for observed failures of the former's invariance to government spending shocks.

The theoretical economy also yields residual measures analogous to the Solow residual. These measures were applied to U.S. quarterly data to obtain a technology shock series that can be compared to the Solow residual. Technology shocks parameterized to reflect the time series properties of this residual account for roughly the same share of output fluctuations in the constant returns to specialization economy studied here as in a competitive RBC economy subject to shocks based on fluctuations in the Solow residual. When increasing returns to specialization are taken into account, the economy exhibits roughly 8% more volatility of output even though the technology shocks are 15% *less* variable than the Solow residual. These results suggest that the extent to which technology shocks can account for aggregate fluctuations may be greater than suggested by competitive models.

The focus of this research, however, was not particular business cycle moments, but rather analysis of the theoretical effects of monopolistic competition and external returns to scale on both the measurement and propagation of technology shocks. Our results show that this combination of market and technological structure has strong implications for RBC theory, and suggest further work in this area to develop estimates of the quantitative importance of this type of thick market effect.

Notes to Tables 1-4 follow Table 4.

Table 1: Standard Deviations of Monopolistically Competitive Economy with <u>*Constant*</u> Returns to Specialization
($\gamma = 1$)

Variable	ρ .6	.7	.8	.9	*Competitive Economy*
z	.95	.95	.95	.95	.95
G	1.58	1.58	1.58	1.58	1.58
C	.91	.91	.91	.91	.91
X	5.51	5.51	5.51	5.51	5.52
K	1.09	1.09	1.09	1.09	1.09
H	.95	.95	.95	.95	.95
N	1.58	1.58	1.58	1.58	–

Table 2: Standard Deviations of Monopolistically Competitive Economy with <u>*Constant*</u> Returns to Specialization
($\rho \in (0,1)$)

Variable	γ 1.	1.1	1.2	1.3	1.4
z	.95	.95	.95	.95	.95
G	1.58	1.43	1.31	1.21	1.12
C	.95	.82	.75	.70	.65
X	5.51	5.01	4.59	4.24	3.92
K	1.09	.99	.91	.84	.78
H	.95	.87	.79	.73	.68
N	1.58	1.43	1.31	1.21	1.12

Table 3: Standard Deviations of Monopolistically Competitive Economy with *Increasing* Returns to Specialization ($\gamma = 1$)

Variable	ρ *.6*	*.7*	*.8*	*.9*	*Competitive Economy*
z	.95	.95	.95	.95	.95
G	5.20	3.33	2.43	1.91	1.58
C	2.92	1.80	1.33	1.07	.91
X	15.98	10.92	8.24	6.61	5.52
K	4.05	2.48	1.75	1.35	1.09
H	2.74	1.88	1.42	1.14	.95
N	3.12	2.33	1.94	1.72	–

Table 4: Standard Deviations of Monopolistically Competitive Economy with *Increasing* Returns to Specialization ($\rho = .7$)

Variable	γ *1.*	*1.1*	*1.2*	*1.3*	*1.4*
z	.95	.95	.95	.95	.95
G	3.33	3.03	2.77	2.56	2.38
C	1.80	1.64	1.50	1.39	1.29
X	10.92	9.93	9.11	8.41	7.80
K	2.48	2.25	2.07	1.91	1.77
H	1.88	1.71	1.57	1.45	1.34
N	2.33	2.12	1.94	1.79	1.66

Notes: In Tables 1-4, moments are computed from simulated data for 5000 periods. The sequence of technology shocks is identical across all experiments and is generated using equation (2) with $\omega = .71$ and $\sigma_\epsilon = .0068$.

Table 5: Cyclical Properties of the U.S. Economy

Variable	*Standard Deviation*	*Correlation with Output*	*First Order Autocorrelation*
G	1.74	1.00	.77
C	1.29	.80	.79
X	5.56	.91	.78
K	.55	.13	.83
H	1.58	.88	.86

Notes: The data is quarterly, covering the period 1960.1-1989.4. G, C, and X refer to gross domestic product, private consumption, gross capital formation respectively in 1982 dollars, (Source: *OECD Main Economic Indicators*). K refers to the gross capital stock in 1982 dollars and was interpolated from the annual gross capital stock and quarterly gross capital formation, (Source: *OECD Flows and Stocks of Fixed Capital*) H denotes total hours of employment (Source: *Citibase*). All statistics are computed from logged and Hodrick-Prescott filtered data.

Table 6: Standard Deviation of Implied Residual: Monopolistically Competitive Economy with *Constant* Returns to Specialization

		ρ .6	.7	.8	.9	1.
γ	*1.0*	.83	.81	.85	.90	.96
	1.1	.89	.92	.98	1.05	–
	1.2	.98	1.04	1.12	–	–
	1.3	1.09	1.18	–	–	–
	1.4	1.22	1.33	–	–	–

Table 7: Standard Deviation of Implied Residual: Monopolistically Competitive Economy with *Increasing* Returns to Specialization

		ρ .6	.7	.8	.9	1.
γ	*1.0*	.91	.68	.65	.77	.96
	1.1	.87	.68	.72	.89	–
	1.2	.83	.71	.81	–	–
	1.3	.81	.75	–	–	–
	1.4	.81	.82	–	–	–

Notes: The moments reported above are sample standard deviations of Hodrick-Prescott trend stationary quarterly residuals from 1960.1-1989.4 measured by the following equation:

$$\ln z = \frac{\gamma}{\lambda + 1/\rho} \ln G - \frac{\rho\gamma - \Omega}{\rho} \ln K - \frac{\Omega}{\rho} \ln H - \Psi. \tag{28}$$

Table 6A: Standard Deviation of Implied Residual Growth: Monopolistically Competitive Economy with *Constant* Returns to Specialization

		ρ .6	.7	.8	.9	1.
	1.0	.72	.70	.71	.73	.76
γ	*1.1*	.78	.78	.80	.83	–
	1.2	.85	.86	.90	–	–
	1.3	.92	.96	–	–	–
	1.4	1.01	1.05	–	–	–

Table 7A: Standard Deviation of Implied Residual Growth: Monopolistically Competitive Economy with *Increasing* Returns to Specialization

		ρ .6	.7	.8	.9	1.
	1.0	.58	.54	.57	.66	.76
γ	*1.1*	.58	.57	.64	.74	–
	1.2	.60	.62	.72	–	–
	1.3	.62	.68	–	–	–
	1.4	.66	.75	–	–	–

Notes: The moments reported above are sample standard deviations of quarterly residual growth rates for 1960.2-1989.4 measured by the following equation:

$$\Delta \ln z = \frac{\gamma}{\lambda + 1/\rho} \Delta \ln G - \frac{\rho\gamma - \Omega}{\rho} \Delta \ln K - \frac{\Omega}{\rho} \Delta \ln H. \tag{28'}$$

Notes to Tables 8-10 follow Table 10.

Table 8: Standard Deviations of Economies with Implied Residuals

Variable	*Competitive Economy*	*Constant Returns to Specialization*	*Increasing Returns to Specialization*
z	.95	1.07	.82
G	1.57	1.59	1.69
C	.86	.93	.87
X	5.59	5.99	6.67
K	1.02	1.22	1.11
H	.97	.94	1.05
N	–	1.59	1.41

Table 9: Contemporaneous Correlations with GNP of Economies with Implied Residuals

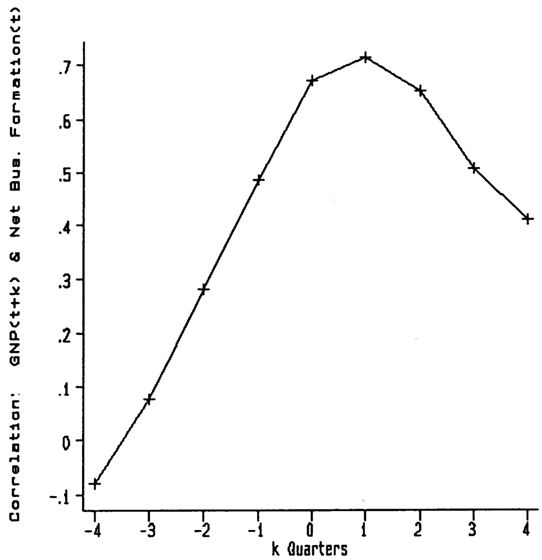
Variable	*Competitive Economy*	*Constant Returns to Specialization*	*Increasing Returns to Specialization*
z	.93	.93	.89
G	1.00	1.00	1.00
C	.48	.53	.44
X	.87	.85	.89
K	.45	.52	.45
H	.84	.81	.86
N	–	1.00	1.00

Table 10: Autocorrelations of Economies with Implied Residuals

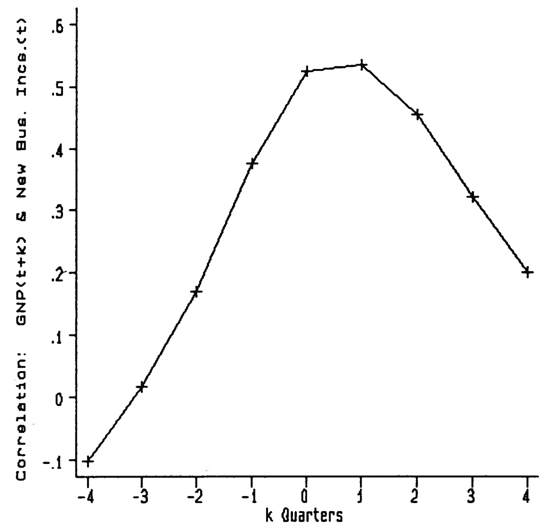
Variable	*Competitive Economy*	*Constant Returns to Specialization*	*Increasing Returns to Specialization*
z	.70	.69	.65
G	.86	.86	.84
C	.33	.41	.38
X	.68	.65	.62
K	.99	.99	.99
H	.67	.64	.61
N	–	.86	.84

Notes: In Tables 8-10, moments are computed from unfiltered simulated data for 5000 periods. In the monopolistically competitive economies, $\rho = .8354$ and $\gamma = 1.1416$ as taken from Morrison (1990). The sequence of technology shocks for each economy is generated using equation (2) with the following parameters for each economy:

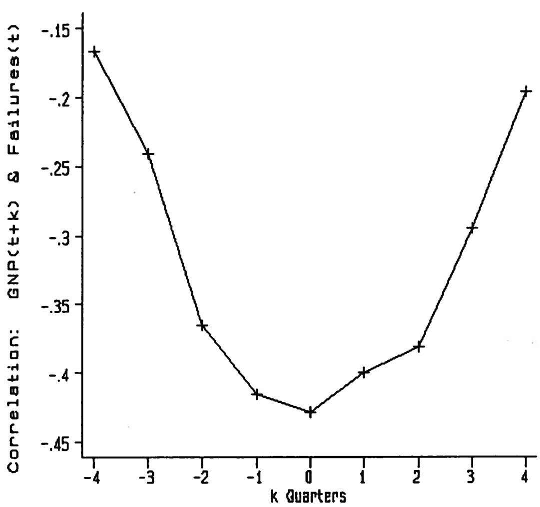
Competitive: $\omega = .71$, $\sigma_\epsilon = .0068$
Constant Returns to Specialization: $\omega = .70$, $\sigma_\epsilon = .0076$
Increasing Returns to Specialization: $\omega = .64$, $\sigma_\epsilon = .0063$



1A: Net Business Formation



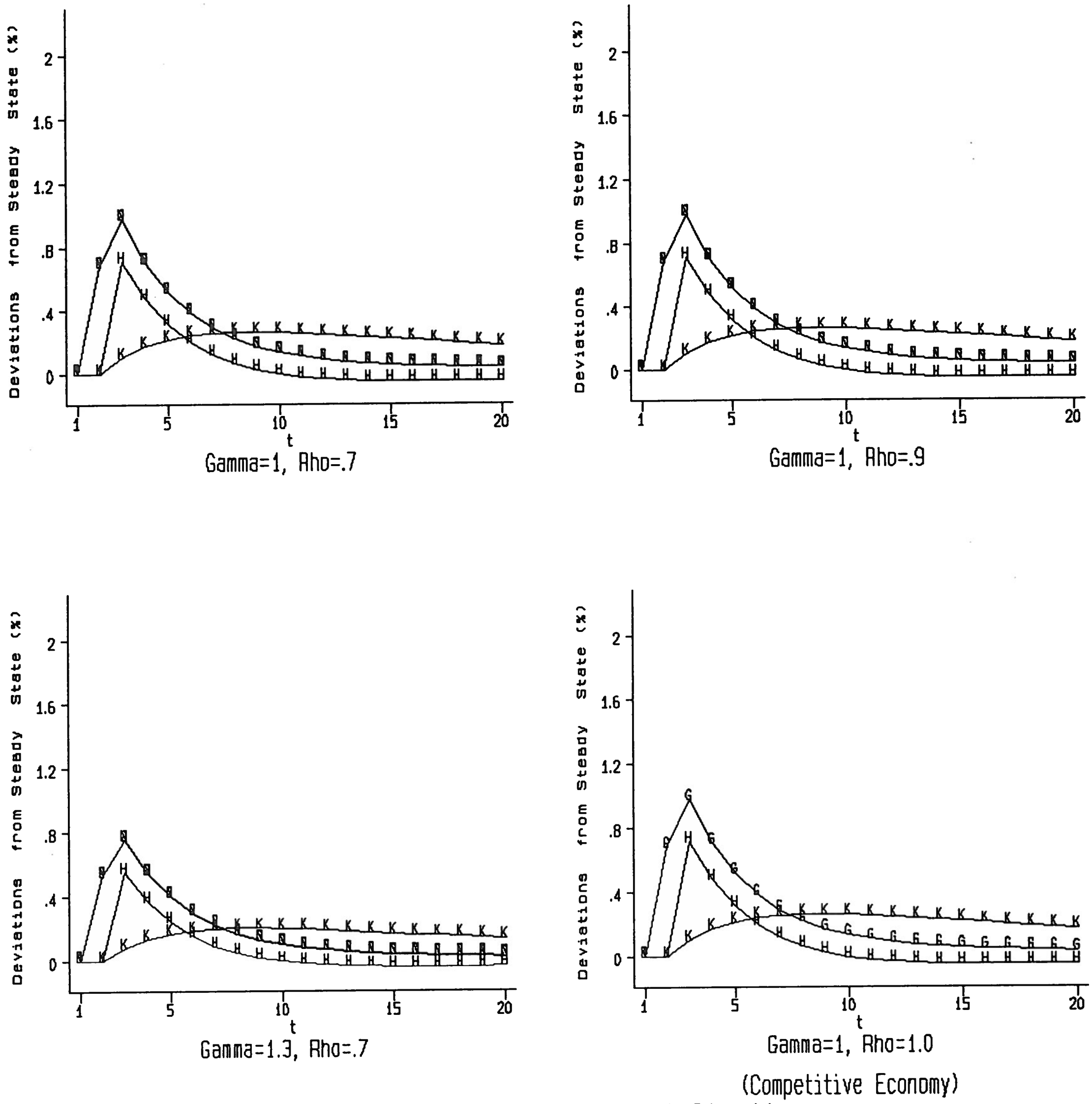
1B: New Business Incorporations



1C: Business Failures

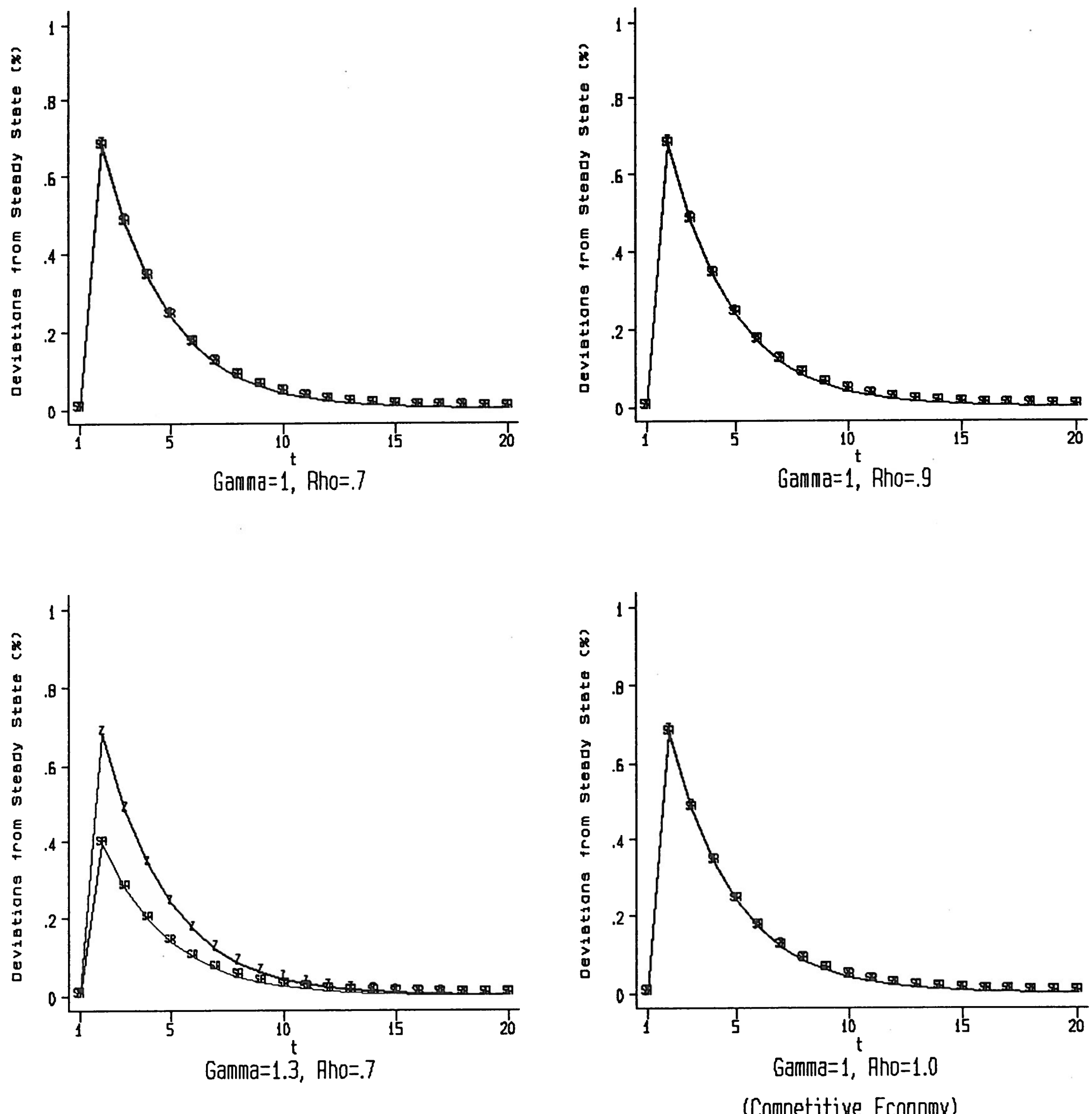
Figure 1: Cyclical Properties of Entry and Exit

Notes: All data is quarterly U.S. data from 1960.1-1989.4. Correlations are computed from Hodrick-Prescott filtered data. Net Business Formation, New Business Incorporations, and GNP (1982 dollars) were obtained from Citibase. Net Business Formation refers to an index based on number of new business incorporations and number of business failures, seasonally adjusted. Business Failures refers to number of bankruptcies as reported in Dun & Bradstreet's Record of Business Closings.



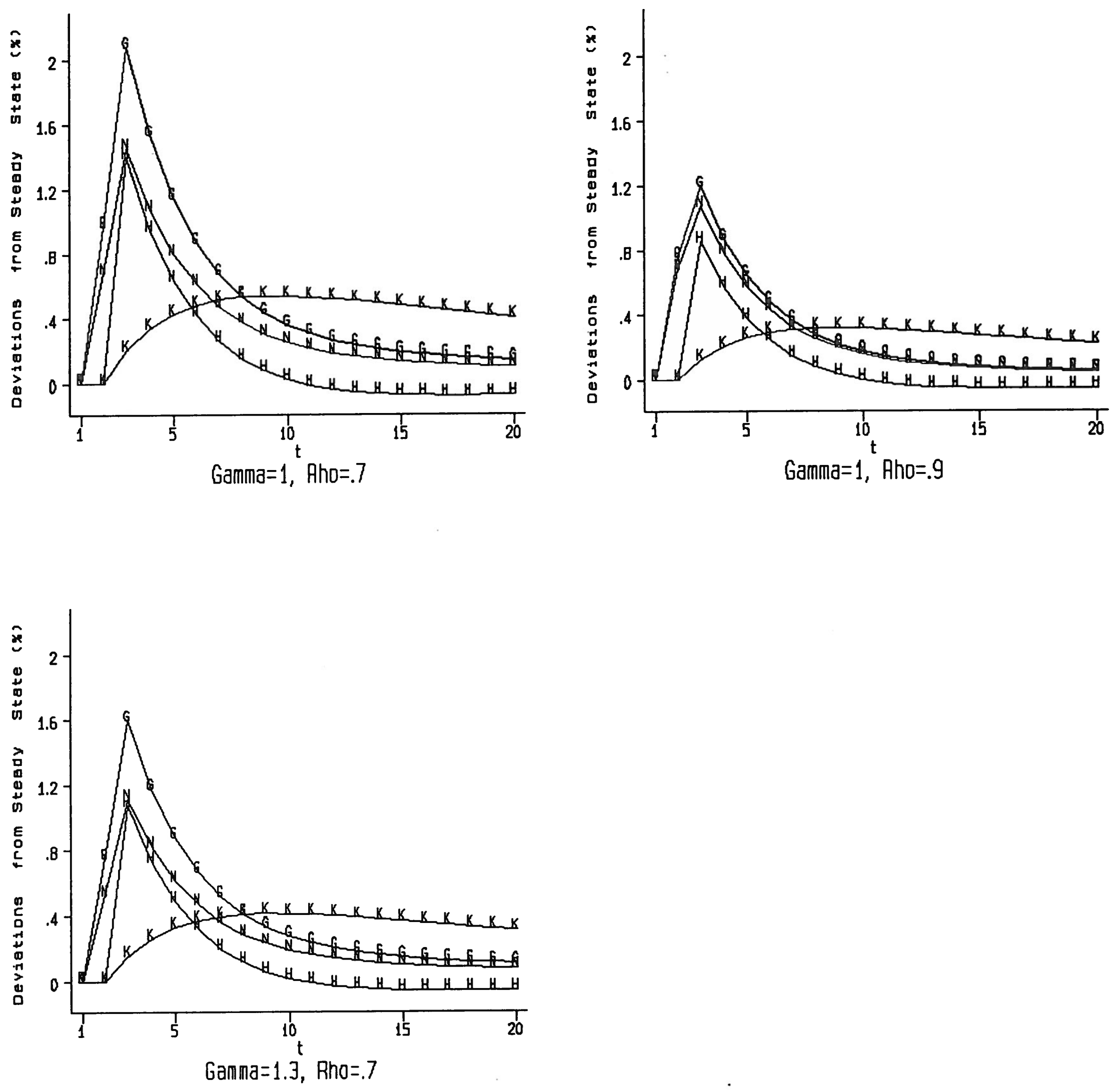
Constant Returns to Specialization

Figure 2: Response to Technology Shock



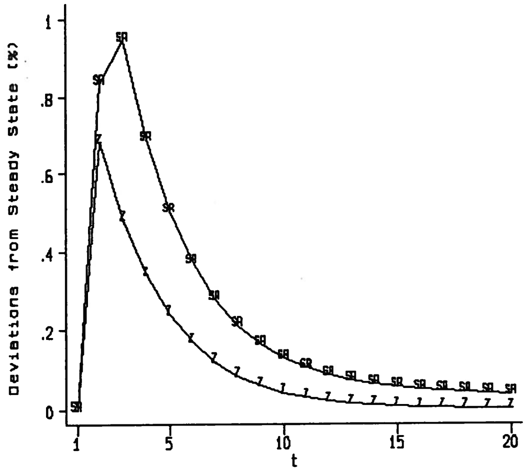
Constant Returns to Specialization

Figure 2B: Response to Technology Shock

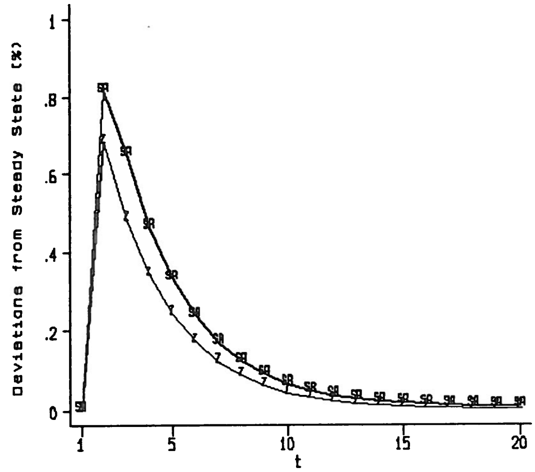


Increasing Returns to Specialization

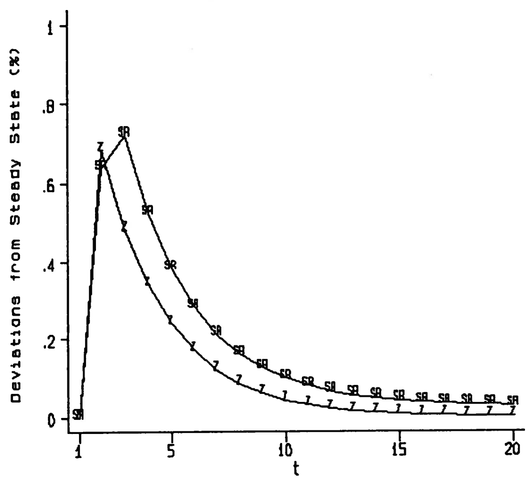
Figure 3: Response to Technology Shock



Gamma=1, Rho=.7

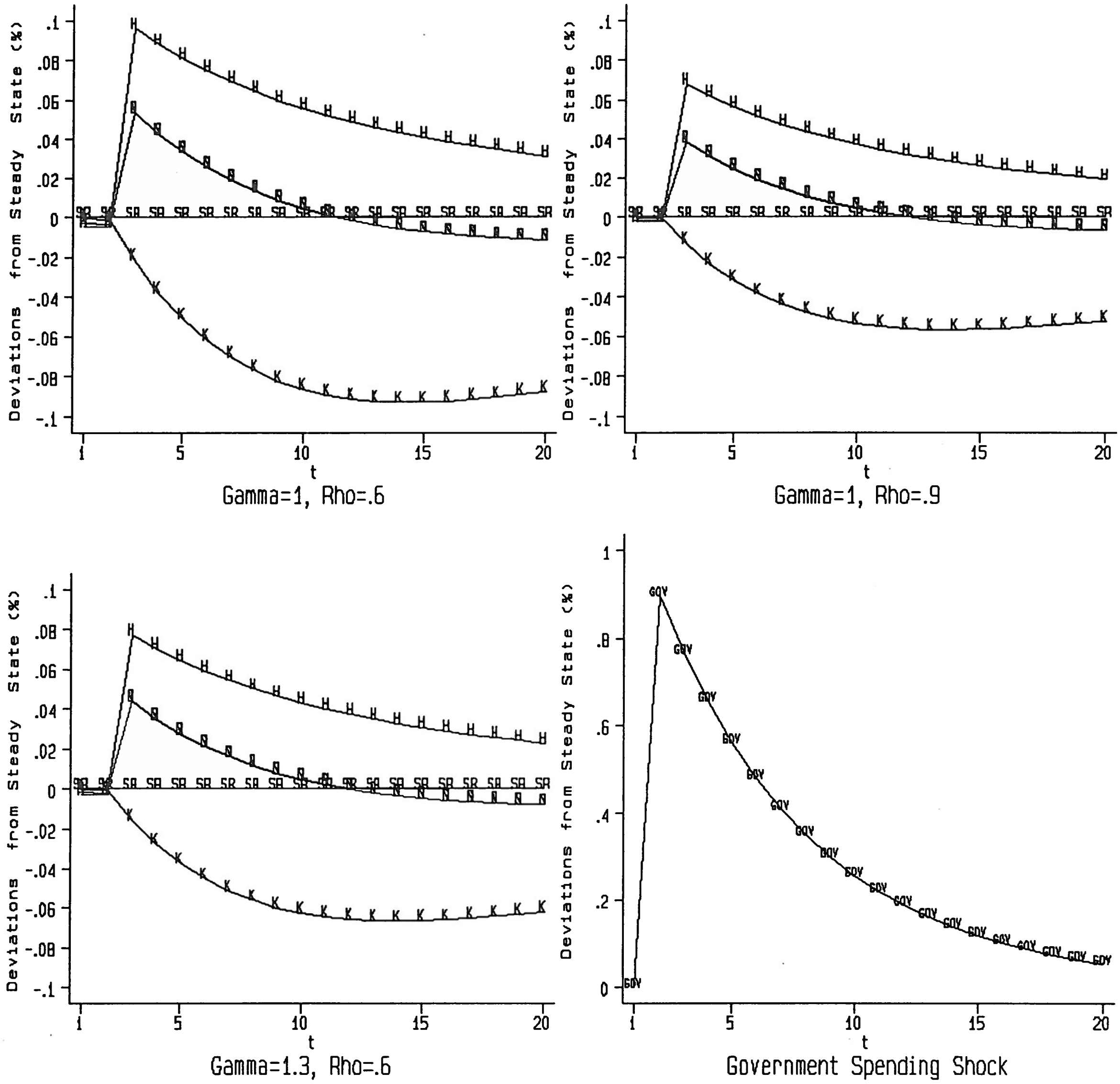


Gamma=1, Rho=.9



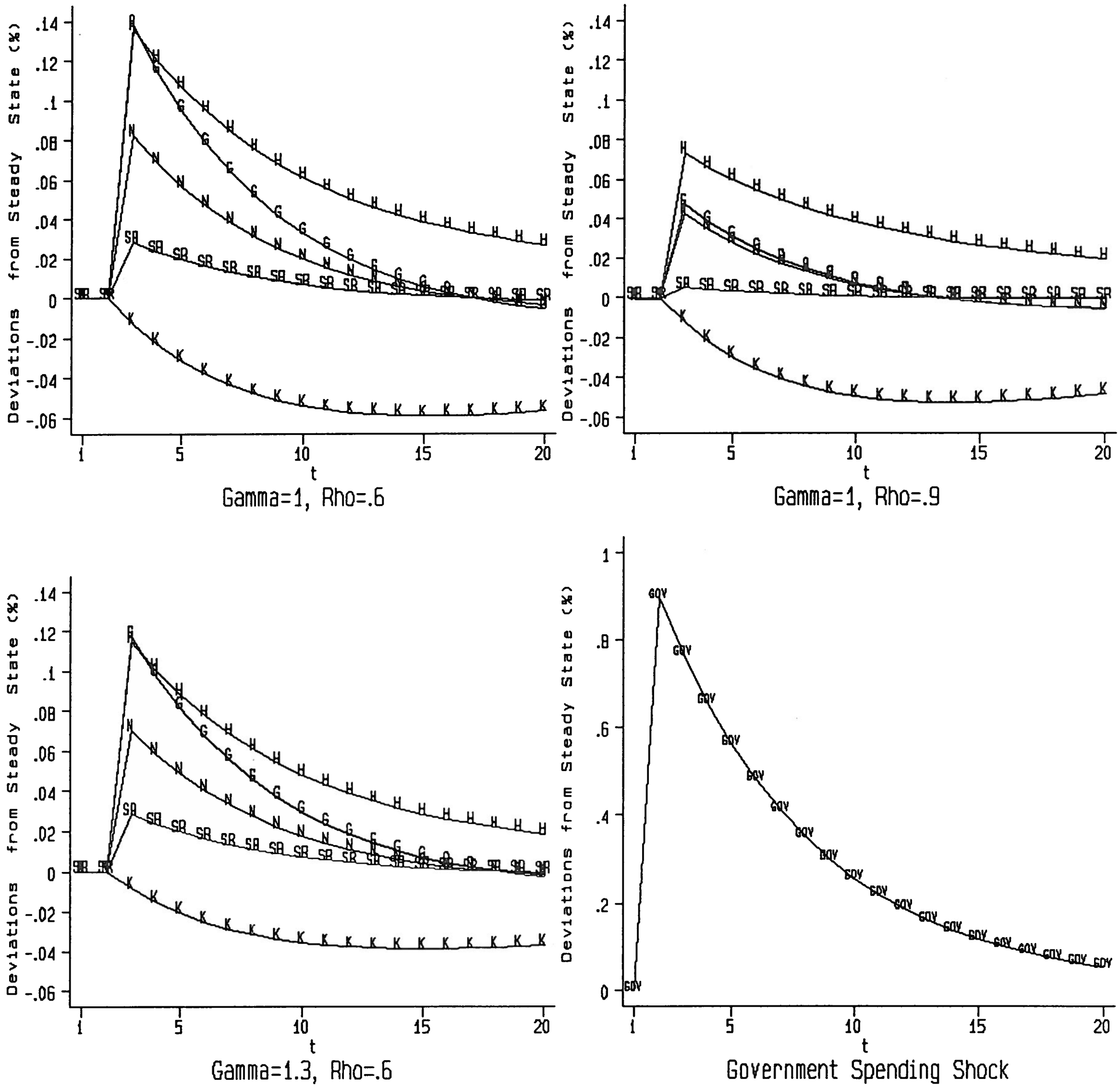
Gamma=1.3, Rho=.7

Increasing Returns to Specialization
Figure 3B: Response to Technology Shock



Constant Returns to Specialization

Figure 4: Response to Government Shock



Increasing Returns to Specialization

Figure 5: Response to Government Shock

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