AN EXPLORATION INTO THE EFFECTS OF DYNAMIC ECONOMIC STABILIZATION

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Abstract

This paper analyzes the stochastic properties of a dynamic general equilibrium model under two government policies which might be interpreted as 'countercyclical' fiscal policies. In one case, we examine the effects on fluctuations of government spending on infrastructure investment in an economy in which public capital is an input to the aggregate production function. In the other, we examine the effects on aggregate business cycle fluctuations of a proportional tax on lay-offs. Our results find only weak evidence for the stabilizing effects of either policy.

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1 Introduction

This paper is an attempt to characterize the dynamic implications of two policies which could be interpreted as schemes designed to "stabilize" the behavior of an economy. This is an attempt to characterize the effects of certain policies, within the context of a dynamic equilibrium model. Such a inquiry would seem long overdue since many of the traditional stabilization policies are described within environments which are neither dynamic, nor equilibrium. Employing a general equilibrium model permits us to characterize the full equilibrium and welfare effects of these policies.

Traditional discussions of countercyclical government policies seem to have as their basis some notion of a static model. With the advent and continued use of dynamic stochastic general equilibrium models, there has been a dramatic decline in the study of this particular issue. This is somewhat surprising since this is exactly the type of model in which dynamic stabilization can potentially make sense. However, the lack of the study of this issue is partly attributable to the fact that in many of the existing business-cycle models, the resulting allocations are optimal, despite the presence of the fluctuations. Nevertheless, it would be possible to use such a model to characterize the feasibility, as well as the welfare costs or benefits derived from many stabilization schemes.

The customary textbook explanations of the conduct of countercyclical stabilization policy are well known. First, there is the implementation of rules governing monetary policy so as to minimize fluctuations in some target variable such as GNP. The trouble with analyzing such a policy is that it is difficult to construct a dynamic general equilibrium model in which monetary policy can have much of an impact. For example, the popular model of Cooley and Hansen [7] has the implication that the cyclical aggregates are virtually invariant to the behavior of monetary policy.[1] Within the context of some non-equilibrium models, monetary policy can have a real impact by exploiting some misperceptions or non-rational behavior. It is difficult, though, to imagine a central bank being capable of systematically capitalizing on such behavior. It is yet even more difficult to construct a model where such a policy is desirable, in the sense that it increases welfare. Many researchers feel that simple asset exchanges, of the sort undertaken through open market operations, seem unlikely to dramatically influence the aggregate behavior of agents, nor their welfare, by significantly altering the incentives for employment or investment.

The second channel in which policy choices can influence economic activity is through fiscal policy. It would seem there is much more latitude in this instance

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[1] Christiano and Eichenbaum [5] study the liquidity effect within a similar model, but again the effect of monetary policy appears to be negligible.

for having these policies influence economic behavior since the distortions that these policies can impose can be substantial. Again, textbook descriptions of counter-cyclical policies would consist of the following examples: progressive taxation or otherwise utilizing pro-cyclical tax rates, increased transfer payments, unemployment insurance, or increased government spending, perhaps on such things as on public infrastructure.

Now some of these policies seem particularly insipid or even ineffective. For example, merely having government increase transfer payments to individuals is not likely to have a noticeable effect on aggregate economic activity. If this policy is financed by a lump-sum tax it seems unlikely to have any effect. If it is financed by an increase in the government debt, then this must entail an increase in future (net) taxes and again is unlikely to have much impact.

The appropriate use of distortional taxation has the potential of having a dramatic impact on the cyclical behavior of an economy. Greenwood and Huffman [8] show how state-contingent tax rates can be configured so as to reduce the fluctuation in output.[2] Not surprisingly, in some states of the world with low capital stocks and "bad" technology shocks, the income tax rate should be reduced.

Unemployment insurance is also a popular scheme utilized in many market economies. However, in a complete market framework it is difficult to imagine how such a policy would be desirable or be able to dramatically influence economic activity. Alvarez and Veracierto [1] show that it may be desirable for such a policy if markets are incomplete. Similarly, Hansen and İmrohoroglü [10] show, within the context of a model without aggregate uncertainty but with incomplete markets, that there may be a significant welfare gain from adopting such a policy, but that it may be the case that the observed levels of replacements rates are not optimal.

In light of this literature, the approach adopted here will be to focus on analyzing two particular stabilization policies. First of all, we will analyze a model in which the government can invest in public infrastructure, which is productive in the sense that it enters as an argument into the production technology.

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[2] Greenwood and Huffman also mention that it is not clear what is meant by the term "stabilization policy". Does one mean that *all* fluctuations should be eliminated or curtailed, or does one mean that only the movements in some aggregates which are below some notion of "trend" should be eliminated. Furthermore, should one focus on fluctuations in aggregate output or consumption? If the latter, then what about movements in the sub-categories such as durable and service consumption? And what about fluctuations in employment and investment? Here it gets a little tricky since it may be possible to stabilize output by implementing policies which encourage workers to work when they might otherwise choose not to do so. It is indeed possible to construct an economy in which fluctuations in one aggregate, such as consumption or output, might be ameliorated by *magnifying* the fluctuations in some other variables, such as employment. It seems that in a world populated by agents who have the usual time-separable preferences, one might be interested in smoothing the utility derived by agents in each period. Yet one does not usually hear the discussion cast in these terms.

Since the 'public works' programs of the Great Depression, packages of government purchases[3] which have been viewed, at least by their authors, as 'stimulative' have often taken the form of expenditures on infrastructure. This may simply be due to the fact that politically, in spite of the 'textbook' Keynesian view that 'spending is spending', mustering support for unproductive purchases—'digging holes and them filling them'—is difficult.[4] On the other hand, we also have evidence, beginning with Aschauer [2], that public infrastructure is a potentially important factor in the economy's aggregate production function. It is from this potentially productive role of public capital that our interest in this policy derives. In particular, in a world with productive public capital, and in which fluctuations in output are to a large extent driven by technology shocks, there seems to be a very real danger that the desire to use government investment as an instrument of 'countercyclical' policy may be inconsistent with the optimal timing of public investment, in the sense that times of high output may in fact be good times to investment, rather than *vice versa.*

To examine this possibility, we construct a modified version of the basic neoclassical model in which public capital enters as an input to the production function. We then conduct experiments which look at the cyclical volatility and correlations of key macroeconomic aggregates under alternative specifications of the policy rule by which government investment is determined.

Secondly, we will analyze a model in which there is a government penalty levied on layoffs, or firing of workers. Such a policy could potentially have a stabilizing effect, since this could reduce the fluctuations in employment over the cycle. The approach adopted here will be to develop a model similar to that studied by Hopenhayn and Rogerson [11]. They do not look at cyclical fluctuations and the period in their model is defined to be 5 years. They also analyze a model in which there are many firms that are subject to idiosyncratic technology shocks and consequently there is movement of workers from firm to firm. The goal here is to analyze the impact of a similar policy on aggregate business cycle fluctuations, and the period is assumed to be a quarter.

So that we can focus solely on the impact of these policies, our analysis will be conducted within a simple and otherwise standard business cycle model. In fact, the starting point will be the basic framework of Hansen [9].

The rest of this paper is organized as follows. Section two examines the model with public capital. Section three examines the model with a layoff-tax. We offer some final remarks in section four. An appendix, section five, contains some details of the solution methods we employed.

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[3] As opposed to transfers.

[4] Witness the President's proposed, and defeated, 1992 package of resurfacing tennis courts and building swimming pools.

2 Public Investment as a Stabilizer

This section of the paper examines the consequences of countercyclical fiscal policy for the behavior of macroeconomic aggregates in an economy in which public investment is productive. Unlike standard real business cycle models, which typically have no productive role for government fiscal policy, this model is one in which an appropriately chosen fiscal policy can be welfare-enhancing. In fact, since the production technology in our model has government capital as an essential input, any fiscal policy which involves positive investment will be at least as desirable as, and in most cases strictly preferred to, a policy of no investment.

The more precise question we wish to address is whether countercyclical policies—which increase government investment when aggregate output is low—are preferable to procyclical policies. We consider two specifications for the government's investment policy rule. In one specification, the level of government investment, relative to the economy's exogenous technology level, depends solely on the level of similarly normalized aggregate output, so that procyclical and countercyclical policies may be defined in a relatively unambiguous way. In our second specification, we model investment policy as a feedback rule from the economy's state vector—which consists of the public and private capital stocks, the realization of the economy's technology shock and the level of government consumption expenditures—to the level of government investment expenditure.

Intuitively, if the technology in our economy with productive government capital is not too different from the technology in the standard RBC model—*i.e.*, if the production coefficient on public capital is not too large—and if government investment is being chosen optimally, then the signs of relationships between public investment and the state variables should be the same as in the standard model. This implies, for example, that government investment should be high when the aggregate capital stock is low or when the economy experiences a favorable shock to technology.

Since low aggregate capital and positive technology shocks have opposite effects, *ceteris paribus*, on aggregate output, one obvious conclusion is that an optimal policy—if one exists—cannot be described simply as 'procyclical' or 'countercyclical'. The optimal response to low output depends crucially on *why* output is low. If output is below trend because capital is low, government investment should be high; the opposite is true if output is low because the economy has experienced a negative technology shock.

2.1 The model economy

2.1.1 Preferences and technology

The model is populated by a continuum of identical, infinitely-lived agents, with unit mass. The typical agent evaluates stochastic streams of consumption

$c_t \geq 0$ and labor hours $n_t \in [0,1]$ according to the intertemporal von Neuman-Morgenstern criterion

$$E_0 \left\{ \sum_{t=0}^{\infty} \beta^t u(c_t, n_t) \right\}. \tag{1}$$

We assume that the momentary utility function u is as in Hansen [9]:

$$u(c,n) = \ln(c) - \psi n. \tag{2}$$

Such preferences, which imply an infinite elasticity of labor supply, may be derived from a model where individual agents have finite elasticities of labor supply, but must supply indivisible amounts of labor, and trade in lotteries over employment. The substance of our results should be robust with respect to this assumption.

The production sector of the economy is characterized by a production function F which has capital, k, and hours, n, as inputs, and is, additionally, subject to an exogenous technology shock, λ. Productive government capital is modelled by having F depend also on the size of the stock of public capital k^g. We assume that the production function F displays constant returns to scale in the privately provided inputs k and n, but increasing returns overall. Constant-returns-to-scale in the privately provided inputs means that number of firms in this economy is indeterminate, and we may as well assume that production takes place within a single representative firm.

The specific functional form which we adopt is the Cobb-Douglas form

$$F(k, n, \lambda; k^g) = (\lambda)^{1-\alpha-\zeta} k^{\alpha} n^{1-\alpha} (k^g)^{\zeta},$$

where $\alpha \in (0,1)$ and $\zeta > 0$. We take the technology shock λ as being raised to the power $1-\alpha-\zeta$ in order to maintain consistency with balanced growth of all quantities save hours. When $\zeta = 0$, our specification reduces to the standard neoclassical technology with labor-augmenting technical change.

The economy faces a sequence of resource constraints which restrict the sum of the components of aggregate demand—private consumption, private investment, x_t, and government purchases, g_t—to be less than or equal to available output:

$$F(k_t, n_t, \lambda_t; k_t^g) \equiv y_t \geq c_t + x_t + g_t.$$

Government purchases, in turn, are divided between government consumption and government investment:

$$g_t = c_t^g + x_t^g.$$

The two capital stocks follow standard laws of motion

$$k_{t+1} = (1-\delta) k_t + x_t$$

and

$$k_{t+1}^g = (1-\delta_g) k_t^g + x_t^g,$$

where δ and δ_g are, respectively, the depreciation rates of private and public capital.

There are two exogenous stochastic processes in this economy, one being the process for the technology shock, λ_t. We also treat government consumption, c_t^g, as following an exogenous stochastic process. The innovations to technology are assumed to be permanent. In particular, the technology shock λ_t is assumed to follow a random walk with drift in logarithms:

$$\ln(\lambda_t) = \ln(\lambda_{t-1}) + \epsilon_t,$$

where $\{\epsilon_t\}$ is a serially uncorrelated *i.i.d.* process with mean μ and standard deviation σ_ϵ.

As in Christiano and Eichenbaum [6], we define the stochastic process for government consumption *relative to the level of the technology shock* λ as

$$\ln(c_t^g/\lambda_t) = (1-\rho_g)\,\nu + \rho_g \ln(c_{t-1}^g/\lambda_{t-1}) + \xi_t,$$

where $\{\xi_t\}$ is also serially uncorrelated and *i.i.d.*, with mean zero and standard deviation σ_ξ. The parameter ν represents the unconditional mean of $\ln(c_t^g/\lambda_t)$. As we will choose units so that the long-run value of output relative to the technology shock, y_t/λ_t, is one, we can interpret ν as the logarithm of the long-run share of government consumption in output.

Note that we have chosen to treat government consumption as output which is simply 'thrown away'. This should not be construed as an assumption regarding the welfare consequences of government consumption. We could, alternatively, let the agent's utility depend on the amount of government consumption, so long as this dependence takes the form

$$u(c, n, c^g) = \ln(c) - \psi n + v(c^g),$$

without affecting our results.

2.1.2 Government policy

In order to keep the model simple, and to focus on the effects of government investment expenditures, we assume that government purchases are financed through lump-sum taxes. Relaxing this assumption may be an interesting avenue for further research. Letting τ_t denote lump-sum tax revenue at date t, the government faces a budget constraint in each period given by:

$$\tau_t = c_t^g + x_t^g.$$

As regards the government's investment policy, we consider two alternative specifications. The first specifies a direct relationship between the level of government investment expenditures and aggregate output, while the second allows the level of government investment expenditure to depend separately on the components of the state of the economy.

In order to be consistent with balanced growth, given the exogenous process for technological change, the policies which we specify determine the level of government investment *relative to* λ as functions of quantities which are themselves taken relative to λ. Precisely, our first specification sets

$$x_t^g = \lambda_t \Gamma\left(y_t/\lambda_t\right), \tag{3}$$

while our alternative specification specifies the level of government investment at each date t as a function of the state of the economy as

$$x_t^g = \lambda_t \Phi\left(k_t/\lambda_t, k_t^g/\lambda_t, c_t^g/\lambda_t\right). \tag{4}$$

These specifications will be consistent with mean growth of λ_t, and all quantities save hours, at rate μ. Other specifications are possible, but lead either to unbalanced paths or possibly degenerate steady states in which the level of government investment expenditure is zero. Below we discuss some of the implications which these specifications have for defining notions such as 'procyclical' and 'countercyclical' policy.

2.1.3 Market structure and equilibrium

The economy is assumed to be competitive. Individuals supply labor and capital to firms at competitively determined wage and rental rates. Government capital is treated as an unpaid factor of production, so that under constant returns to the privately provided inputs and competition in factor markets, firms will earn zero profits.

Individuals divide their income between expenditures on consumption, investment and lump-sum tax payments to the government. Individuals understand the stochastic processes for the exogenous variables, the dependence of prices on the state of the aggregate economy, and the policy rule followed by the government, but take as given the aggregate state and its law of motion. In equilibrium, individual and aggregate quantities coincide.

The conditions which describe an optimum for the individual, in addition to the budget constraint and law of motion for individual capital, are

$$-u_2\left(c_t, n_t\right) + u_1\left(c_t, n_t\right) w_t = 0$$

—the standard intratemporal efficiency condition equating the marginal rate of substitution between consumption and leisure at each date t to the real wage rate w_t—and the Euler equation

$$u_1\left(c_t, n_t\right) = \beta E_t\left\{u_1\left(c_{t+1}, n_{t+1}\right)\left[1 + r_{t+1} - \delta\right]\right\},$$

where r_{t+1} is the rental rate on capital at date $t+1$.

In equilibrium, individual and aggregate variables coincide, and the prices w and r satisfy

$$w_t = F_2\left(k_t, n_t, \lambda_t; k_t^g\right)$$

and

$$r_t = F_1\left(k_t, n_t, \lambda_t; k_t^g\right).$$

2.2 Calibrating and solving the model

The equilibrium allocations for this economy can be obtained, in a straightforward way, as solutions to a restricted social planning problem, in which individual utility is maximized subject to the economy's resource constraint, taking as given the government policy rule and the behavior of aggregate quantities. That is, equilibrium allocations solve

$$\max E_0 \left\{ \sum_{t=0}^{\infty} \beta^t u\left(c_t, n_t\right) \right\}$$

subject to

$$F\left(k_t, n_t, \lambda_t; k_t^g\right) + (1-\delta) k_t - c_t^g - x_t^g \geq c_t + k_{t+1},$$

where x_t^g is assumed to follow either $x_t^g = \lambda_t \Gamma\left(\bar{y}_t/\lambda_t\right)$ or $x_t^g = \lambda_t \Phi\left(\bar{k}_t/\lambda_t, k_t^g/\lambda_t, c_t^g/\lambda_t\right)$, with $\bar{k}_t$ and $\bar{y}_t$ denoting aggregate capital and output. Once we obtain the efficiency conditions characterizing the solution to this problem, we impose the consistency conditions $\bar{k}_t = k_t$ and $\bar{y}_t = y_t$.

In terms of non-linearity, the model of this section—in contrast to our second model below—is not too different from the basic neoclassical model. Thus, our solution strategy for this section follows that of King, Plosser and Rebelo [12] and involves approximating the efficiency and equilibrium conditions in a linear fashion. Given that the technology shock follows a geometric random walk with drift, we first transform all variables, with the exception of labor hours, by dividing them by the level of λ. We then approximate the equations around the deterministic steady state, obtaining a linear system with all (transformed) variables expressed as percentage deviations from steady state. We then eliminate the controls, consumption and hours, and solve the resulting difference equation in the endogenous states, costate and exogenous variables under certainty equivalence. Finally, the stochastic trend is put back in to obtain paths for the log-levels of the untransformed quantities.

The stochastic properties of the endogenous states, control variables, and other variables of interest—in particular, their second moment properties—can then be recovered, and artificial time series simulated. As we do also in the next section, we generate a sample of artificial time series for the variables of interest, which we then detrend using the Hodrick-Prescott filter.

The model's parameters are $\{\psi, \beta, \alpha, \zeta, \delta, \delta_g, \rho_g, \nu, \sigma_\epsilon, \sigma_\xi\} \equiv \Theta$, and the parameters of $\Phi(\cdot)$ and $\Gamma(\cdot)$. We consider first the parameters in the list Θ. The leisure parameter ψ can be set to one, which just amounts to a rescaling of the units in which hours are measured. The model's time period corresponds to one quarter, so we set the discount factor β equal to .99, which corresponds roughly to a 6.71% steady state annual rate of return on capital. We follow standard practice in setting α, capital's share of national income, to be .36 and the depreciation rate of the private capital stock, δ, to .02. We have not estimated δ_g, but since public capital consists primarily of structures, a good ballpark estimate should be that δ_g is roughly half δ, or $\delta_g = .01$, which is the number we adopt in this version of the paper.

In our experiments we allow the parameter ζ, which is public capital's 'share' in the Cobb-Douglas production function, to vary from $\zeta = .10$ to $\zeta = .30$. This range of values is in line with the estimates of Aschauer [2].

As for the exogenous stochastic processes governing technological change and government consumption, we follow Christiano and Eichenbaum [6] in setting the persistence parameter for the government consumption process at $\rho_g = .96$. We set the parameter ν of the government consumption process so as to yield an 18% share of government consumption in aggregate output in steady state. Finally, we set the standard deviations of the inputs to the technology shock and government consumption processes to be $\sigma_\epsilon = .015$ and $\sigma_\xi = .021$.

Given our linear approximation method, the key parameters of the investment policy functions can be expressed as elasticities. For example, when government investment follows the policy rule $x^g/\lambda = \Gamma(y/\lambda)$, a sufficient parameter for our computations is $\eta_y \equiv z\Gamma'(z)/\Gamma(z)$, evaluated at the steady state. Hence, the percentage deviation of the transformed variable x^g/λ from its nonstochastic steady state level, which we denote by $\hat{x}^g$, is related to the percentage deviation of y/λ from its steady state by

$$\hat{x}^g = \eta_y \hat{y}.$$

When investment follows the alternative rule $x^g/\lambda = \Phi(k/\lambda, k^g/\lambda, c^g/\lambda)$, we specify the parameters η_k, η_k^g, and η_c^g in

$$\hat{x}^g = \eta_k \hat{k} + \eta_k^g \hat{k}^g + \eta_c^g \hat{c}^g.$$

The steady state level of government investment, as a fraction of output, is set at 1.5%, which is approximately the average value of government purchases of durables and structures relative to GDP for the US in the post-World War II period. We also conduct some hypothetical experiments where this value is doubled, to 3%.

2.3 Results

We performed a wide range of experiments with public investment as a function either of output or the state of the economy, with various values of the public capital productivity parameter, ζ, and with policies that run the gamut from extremely ‘procyclical’ to extremely ‘countercyclical’. The uniform conclusion of these experiments is that public investment policy does not impact much on the cyclical volatility of either consumption or output, though there is a modest stabilizing effect on both hours and investment as public investment becomes more ‘countercyclical’.

The first set of experiments consider government investment policy set according to (3)—that is, as a function of output (relative to the level of the technology shock λ). Note that even for this simple rule, given the presence of the technology shock λ, ‘procyclical’ and ‘countercyclical’ are not unambiguously defined. In particular, the rule already incorporates a feature which, as we argued in the introduction to this section, has some measure of optimality to it—namely, a positive response of public investment to a good technology shock. With $x^g = \lambda\Gamma(y/\lambda)$, if $\Gamma' < 0$—which is a potential definition of ‘countercyclical’ for this policy rule—we also have x^g increasing in λ. The results of this section need to be interpreted with this consideration in mind—even in attempting to examine a ‘naive’ policy rule, we in fact are stuck with one which is actually a bit sophisticated.

The experiments which we conducted for this rule are as follows. For each of $\zeta = .10$, $\zeta = .20$ and $\zeta = .30$, we varied the ‘feedback’ parameter η_y over, roughly, the broadest range consistent with stability of the linear system dynamics. In each case we generated a sample of 500 sets of time series on the variables of interest, each series being of length equal to 150 periods. All series were then detrended using the Hodrick-Prescott filter and sample average second moments calculated. All the numbers in the tables that follow, then, refer to the stochastic properties of the H-P cyclical components of the respective variables.

Table 2.1 reports the standard deviations of output, consumption, hours and private investment for the case of $\zeta = .30$, for values of η_y equal to 2, 1, 0, -1 and -2.

	Value of η_y				
	2	1	0	-1	-2
Output	1.464	1.454	1.438	1.431	1.423
Consumption	1.338	1.336	1.336	1.339	1.340
Hours	0.844	0.820	0.801	0.789	0.780
Private investment	1.778	1.611	1.477	1.402	1.376

Table 2.1. Percent standard deviations of quantities for the case of $x^g = \lambda\Gamma(y/\lambda)$; $\zeta = .30$.

As noted above, there is very little impact of varying η_y on the cyclical volatility of either output or consumption. The relationship between the standard deviation of consumption and η_y is not monotonic, with $\eta_y = 0$ corresponding to the lowest level of cyclical volatility in consumption.[5] This pattern is hardly pronounced, though. The monotonic decline in the standard deviations of hours and private investment, as η_y varies from extremely procyclical to extremely countercyclical is more pronounced. Note that as η_y moves in the countercyclical direction, private investment in fact becomes less volatile than output.

Tables 2.2 reports similar results for the case of $\zeta = .20$. A lower value of ζ—*i.e.*, a smaller share of public capital in the Cobb-Douglas production function—allows us to consider a broader range of values for η_y and still be consistent with stability of the linear system. Here we vary η_y from 3 to -3:

	Value of η_y						
	3	2	1	0	-1	-2	-3
Output	1.569	1.561	1.561	1.564	1.552	1.549	1.530
Consumption	1.326	1.328	1.328	1.338	1.328	1.333	1.328
Hours	0.939	0.925	0.921	0.918	0.916	0.913	0.894
Private investment	2.308	2.212	2.123	2.070	1.979	1.916	1.838

Table 2.2. Percent standard deviations of quantities; $\zeta = .20$.

Again, the volatility of consumption and output do not change much, while the volatility of hours and investment decline as the policy parameters vary from procyclical to countercyclical. The decline in the volatility of hours is somewhat less pronounced, though.

Finally, table 2.3 gives results for the case of $\zeta = .10$, for values of $\eta_y = 0$ and two 'extremes' of $\eta_y = 5$ and -5.

	Value of η_y		
	5	0	-5
Output	1.718	1.721	1.711
Consumption	1.334	1.336	1.336
Hours	1.046	1.049	1.046
Private investment	2.910	2.802	2.703

Table 2.3. Percent standard deviations of quantities; $\zeta = .10$.

With $\zeta = .10$, as one might expect, the impact of varying η_y on the standard deviations of all quantities is greatly reduced. In this case only the standard deviation of private investment shows any discernible relation to η_y, the standard deviations of the other quantities changing only slightly and, in any event, not

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[5] The entries in the $\eta_y = 0$ column differ from the volatilies reported for the basic model by Hansen [9] and others. This is due the fact that with $\eta_y = 0$ government investment is left proportional to the level of technology λ; this in turn feeds into the public capital stock, adding an additional element of volatility.

monotonically. In all of the above experiments steady state public investment is only 1.5% of steady state output, so that even with a large percentage response of public investment to changes in output, the impact on the stochastic properties of the model's time series can be expected to be minor unless small amounts of public investment translate into large productivity gains.

The experiment reported in the following table considers, hypothetically, an economy identical to the one above, except with a steady state ratio of government investment to output twice the 1.5% value used in Tables 2.1–2.3. In order to allow for the greatest impact of the choice of the policy parameter η_y we look at the extreme case of $\zeta = .30$. The table reports the resulting standard deviations for the values $\eta_y = 2$, 0 and -2:

	Value of η_y		
	2	0	-2
Output	1.479	1.445	1.428
Consumption	1.346	1.330	1.334
Hours	0.857	0.828	0.809
Private investment	1.783	1.492	1.380

Table 2.4. Percent standard deviations; $\zeta = .30$; twice-realistic level of government investment.

The first thing to note about the results in table 2.4 is that doubling the steady state output share of public investment raises the cyclical volatility of all quantities except consumption at all values of the policy parameter η_y. This can be seen by contrasting the numbers in table 2.4 with those reported in first, middle and last columns of table 2.1 above, which are for otherwise identical parameters. Other than this difference in level, the effects of varying η_y on the reported volatilities are broadly similar, both in the pattern of dependence and the magnitudes of the changes.

Though not reported in the above tables, in all the preceding experiments, the volatility of the cyclical component of the private capital stock falls somewhat as η_y runs from positive to negative, while the volatility of the cyclical component of the public capital stock increases sharply. It is this increase in the cyclical volatility of k^g which allows the volatility of output to remain fairly constant while the volatility of hours falls.

Variation in η_y also has implications for the correlations between the cyclical components of consumption, hours, investment and output. Table 2.5 gives the correlations with output of consumption, hours and private investment and as η_y varies, for the intermediate case of $\zeta = .20$.

	Value of η_y						
	3	2	1	0	-1	-2	-3
Consumption	.8022	.8069	.8085	.8106	.8085	.8094	.8135
Hours	.5378	.5294	.5287	.5221	.5216	.5147	.5033
Private investment	.8875	.8998	.9138	.9263	.9390	.9499	.9582

Table 2.5. Correlations with output; $\zeta = .20$.

As the policy parameter η_y varies from the 'procyclical' end of the spectrum to the 'countercyclical' end, we see an increase in the procyclicality of both consumption and private investment, and a weakening of the procyclicality of hours. In all of our experiments, the correlations between the cyclical component of output and the cyclical components of both capital stocks (not shown) are slightly negative, the more so the more 'countercyclical' is government investment policy. With the Hansen [9] specification for $u(c, n)$ which we employ, the cyclical behavior of the real wage is identical to that of consumption, so that a more countercyclical investment policy corresponds to a slightly more procyclical real wage.

The next set of experiments which we conduct examine cases where policy is set according to (4)—that is, cases where government investment (normalized relative to λ) is a function of the (also normalized) state variables of the economy, $(k/\lambda, k^g/\lambda, c^g/\lambda)$. As discussed above, we specify the policy in this way, relating 'normalized' levels of investment to 'normalized' values of the state vector, in order to be consistent with steady state growth, given that λ has been assumed to follow a geometric random walk with drift. Unfortunately, this specification allows us to consider in only a limited way the potentially interesting impact of a policy which responds differently to technology shocks and deviations of capital from its steady state. More precisely, when we specify

$$\hat{x}^g = \eta_k \hat{k} + \eta_k^g \hat{k}^g + \eta_c^g \hat{c}^g$$

—where, recall, for any z, $\hat{z}$ is the percentage deviation of the normalized variable z/λ from it deterministic steady state level—the actual level of public investment obeys, locally,

$$\ln(x_t^g) = \gamma + \eta_k \ln(k_t) + \eta_k^g \ln(k_t^g) + \eta_c^g \ln(c_t^g) + (1 - \eta_k - \eta_k^g - \eta_c^g) \ln(\lambda_t)$$

where γ is a constant. In other words, the response of x^g to the technology shock cannot be set independently of the response of x^g to the levels of the two capital stocks (and government consumption). In particular, ignoring government consumption for the moment, we cannot consider the case where the level government investment responds negatively to both capital stocks *and* the technology shock, though a positive response to all three variables is possible.

For simplicity, our first experiments set $\eta_c^g = 0$—no response of government investment to government consumption—and $\eta_k = \eta_k^g = \eta$—an identical percentage response to a given percentage change in either normalized capital stock. We again look at values of the government productivity parameter ζ of .30, .20 and .10, and vary the single 'response' parameter η over as broad a range as is consistent with stability of the model. Table 2.6 records, as above, the percent standard deviations of the cyclical components of output, consumption, hours and private investment for values of η equal to .3, 0 and $-.3$, for the case of $\zeta = .30$.

	Value of η		
	.3	0	$-.3$
Output	1.461	1.438	1.417
Consumption	1.342	1.336	1.332
Hours	0.840	0.801	0.767
Private investment	1.658	1.477	1.362

Table 2.6. Percent standard deviations when x^g is a function of the state; $\zeta = .30$.

It is of interest to contrast the numbers in the last column of table 2.6 with those in the last column of table 2.1. Each set of numbers represents, for the respective policy rule, the greatest admissible amount of 'countercyclicality'—though it is important to remember that for the experiments in table 2.6, this concept is no longer unambiguous. While not greatly different, the volatilities reported in the last column of table 2.6 are uniformly lower than those reported in table 2.1. The patterns of dependence of the numbers on the policy parameter η are, for hours and investment, similar to the pattern that emerged in the experiments above with respect to η_y. There is as well a discernible, and monotonic, effect of η on the volatility of both output and consumption.

How 'pro-' or 'countercyclical' is a policy of $\eta = -.3$? For this specification of x^g as a function of the state, with $\eta < 0$, government investment is negatively related to quantities which increase output—the capital stocks—but positively related to the technology shock. One measure of cyclicality is to look at the correlation between the cyclical components of output and government investment, which is .649. By contrast, the same correlation for the time series generated by the experiment reported in the last column of table 2.1—*i.e.*, the case of $\eta_y = -2$—is .464.

The next two tables report results for the cases of $\zeta = .20$ and $\zeta = .10$. In the first, η takes on values of .4, 0 and $-.4$; the lower value of ζ permits more 'extreme' values than the previous case with $\zeta = .30$.

	Value of η		
	.4	0	$-.4$
Output	1.573	1.564	1.534
Consumption	1.332	1.338	1.328
Hours	0.945	0.918	0.891
Private investment	2.259	2.070	1.866

Table 2.7. Percent standard deviations when x^g is a function of the state; $\zeta = .20$.

The next gives results for $\zeta = .10$. Here, η takes on the values of .6, 0 and $-.6$.

	Value of η		
	.6	0	$-.6$
Output	1.714	1.721	1.716
Consumption	1.339	1.336	1.334
Hours	1.047	1.049	1.049
Private investment	2.926	2.802	2.669

Table 2.8. Percent standard deviations when x^g is a function of the state; $\zeta = .10$.

As with the results in table 2.6, these numbers should be contrasted with their counterparts—tables 2.2 and 2.3—under the previous policy rule $x^g = \lambda\Gamma\left(y/\lambda\right)$.

What conclusions can be drawn from these experiments? First, we have found that moving from policies which might be regarded as 'procyclical' to policies which are more 'countercyclical' stabilizes output and consumption by little, if at all. Investment and hours are marginally stabilized, but whether there are welfare gains from this is not clear. For the preferences of our representative agent, what matters is the volatility of consumption, and there is no great improvement along this dimension.

Also, the outcomes under the two alternative policies which we consider are not too different. Largely, we think, this is due to the fact that under either policy rule the behavior of public investment is, in a sense, dominated by the stochastic trend λ_t. There may, in fact, be something of an 'invariance' result here: when shocks to technology are permanent, and an investment policy is structured to be consistent with balanced growth, the policy has 'built-in' a degree of optimality—a positive response of investment to positive technology shocks—independent of other aspects of the policy.

3 A Tax on Layoffs

In this section we will study a similar economic model to that described in the previous section, but the goal will be to study the impact of a tax on layoffs of workers. To isolate the impact of this policy, it will be assumed that government spending is not productive. Furthermore, there will be a tax imposed on the layoff of workers, and the resulting revenue from this policy will be given back to agents in a lump-sum manner. If the stabilization of output were the ultimate goal, such a policy might seem a reasonable approach since, to a first approximation, the level of output can be changed rapidly only by changing the quantity of the labor input.

Again in this case the preferences are described by equations (1) and (2). Given the indivisible labor structure underlying the Hansen-type utility function (2), the tax on layoffs here really represents a tax on the movement of bodies out of employment, not simply on changes in hours per worker.

For this section, the production technology is of the following form

$$F(k, n, \lambda) = k^{\alpha} (\lambda n)^{1-\alpha} \tag{5}$$

where λ is again the technology shock. It will simplify the analysis to assume that the technology shock follows a random walk in logarithms:

$$\ln(\lambda_t) = \ln(\lambda_{t-1}) + \epsilon_t$$

where $\ln(\epsilon_t)$ is an *i.i.d.*, normally distributed random variable, with mean μ and variance σ_{ϵ}^2. Again, aggregate output must be used for consumption or investment. However, in this case the government may impose a tax on the laying off of workers. Let the level of this tax rate be denoted by θ_t in period t.

The appropriate constraint for the planning problem for the maximization of the utility function of the representative agent is then written as follows

$$c_t + x_t \leq F(k_t, n_t, \lambda_t) - \theta_t \max\{0, n_{t-1} - n_t\} + \tau_t. \tag{6}$$

It is assumed that all revenue generated by the tax on layoffs will be rebated to the individuals in a lump-sum manner. Here τ_t represents the transfer payment and hence in equilibrium $\tau_t = \theta_t \max\{0, n_{t-1} - n_t\}$. Of course, if $n_t > n_{t-1}$, the constraint on layoffs is not binding and $\tau_t = 0$. This revenue could alternatively be assumed to go to some productive purposes, along the lines of that described in the previous section. However, the approach adopted here will more easily enable us to focus on the distortional impact of this particular tax on layoffs alone, without cluttering the results with the impact that other accompanying policies might also produce.

Now the added constraint on the right side of equation (6) adds another "non-linearity" to this problem, although the constraint is still continuous. As is described in the appendix, this added complication will have to be dealt with carefully in the numerical characterization of the model.

Additionally, the capital evolution equation is given by

$$k_{t+1} = (1-\delta) k_t + x_t. \tag{7}$$

It is of interest to look at the optimization conditions for this problem. The Euler equation associated with capital is conventional:

$$u_1(c_t, n_t) = \beta E_t \{u_1(c_{t+1}, n_{t+1}) [F_1(k_{t+1}, n_{t+1}, \lambda_{t+1}) + 1 - \delta]\}. \tag{8}$$

On the other hand, the optimization condition for choice of employment (n_t), which is usually only an intratemporal condition, is now the following *intertemporal* condition:

$$\begin{aligned} -u_2(c_t, n_t) = {} & u_1(c_t, n_t) [F_2(k_t, n_t, \lambda_t) + \theta_t \chi(n_{t-1} - n_t)] \\ & -\beta E_t [u_1(c_{t+1}, n_{t+1}) \theta_{t+1} \chi(n_t - n_{t+1})] \end{aligned} \tag{9}$$

where χ is the indicator function, such that $\chi(x) = 0$ if $x < 0$ and $\chi(x) = 1$ otherwise. It is assumed here that there is an interior solution, and that the value for n_{t+1} is again determined by the optimal decision rule. The reason for this condition is that hiring an additional worker in period t has the usual (intratemporal) costs and benefits, as described by the term on the left side and the first term on the on the right side of the equation. Additionally, employing an additional worker has the benefit of increasing the return in period t by lowering the prospective penalty in period t to laying off workers, if this is actually done $(n_t < n_{t-1})$. Lastly, employing an additional worker in period t has the effect of raising the cost of hiring because there is also the possibility that this worker will have to be laid off in the following period, and the cost of doing so will be θ_{t+1}. Of course, along a path where $n_{t-1} < n_t < n_{t+1}$, the terms involving $\chi(\cdot)$ are zero, and therefore this optimization condition reduces to the usual intratemporal condition.

The details for the solution of the model are contained in the appendix. Because the technology shock (λ) is assumed to be a random walk, this minimizes the number of state variables for the economy. In the appendix it is shown that for the economy in which $\theta_t = \tau_t = 0$, the only state variable is the composite variable (k_t/λ_t). Obviously, if $\theta_t > 0$, then the employment level (n_{t-1}) is also a state variable.

Now it is obviously important to establish some values for the parameters for this economy. The parameters $\{\alpha, \beta, \delta\}$ are again chosen to have the values $\{.36, .99, .02\}$. In this instance the variance for the technology shock innovation σ_ϵ is set equal to .0123, while μ equals .0073.

It is now appropriate to compare the behavior of the various aggregates for the cases in which there is and is not a penalty for layoffs. In particular, it is instructive to examine the decision rules for investment and employment in the two cases. Figure 1 shows the employment decision rule for the case in which $\theta_t = \tau_t = 0$. Obviously, this decision rule depends on the level of the capital stock in an approximately linear manner. Since $\theta_t = \tau_t = 0$, the level of employment in the previous period is not a relevant state variable, and so the level of n_{t-1} does not influence this decision rule. As is apparent, the decision rule for employment is "close to linear," as a function of the transformed capital stock (k_t/λ_t).

Figures 2 illustrates the decision rule for employment when θ_t is set so as to equal one quarter's wages of workers in the steady-state. That is, workers receive a severance payment when laid-off, which is equal to one quarter's wages. As is apparent from the illustration, the level of n_{t-1} now *does* influence the employment decision rule. It is possible to see that employment is increasing in the level of employment in the previous period. This effect is somewhat more pronounced when $n_{t-1} is$ above its steady state level, which is exactly what one would expect.[6] The employment decision rule is less responsive to the level of the capital stock when $\theta > 0$ than when $\theta = 0$. Additionally, the higher is the value of θ, the more sensitive investment will be to n_{t-1}, and the less sensitive to λ_t.

Table 3.1 now shows how the cyclical properties of the model for the benchmark case with no distortions, and also for the case in which θ_t is equivalent to one or two quarter's worth of the steady-state wage of labor. As is apparent from the table, this policy can indeed have a stabilizing effect on the aggregates. When the penalty (θ) is equal to one quarter's wages, the levels of output, investment, and employment exhibit smaller fluctuations. However, consumption and capital exhibit larger fluctuations. The effects of this policy are not monotonic however. When the penalty is raised to two quarters wages, all aggregates, with the exception of the capital stock, exhibit *larger* volatility.

	$\theta = 0$	$\theta = w$	$\theta = 2w$
Output	1.41	1.30	1.44
Consumption	0.85	0.87	0.94
Investment	2.60	2.20	2.52
Employment	0.67	0.50	0.74
Labor Productivity	0.25	0.22	0.24
Capital	0.76	0.85	0.82

Table 3.1. Percent standard deviations for various policies. w denotes one quarter's wages in steady state.

It is also of interest to note that table 3.2 shows that the average level of employment is marginally higher with the layoff penalty than without it. Hence,

---

[6] As equation (9) shows, the steady state level of employment is also changed moderately.

it could be said that the average employment effects are small, and in any event do not appear to increase unemployment. This contrasts with the results of Rogerson and Hopenhayn [11]. They found that such a policy lowered average employment because firms reduced employment in an attempt to avoid having to pay the higher penalty to laying off workers. The difference between their environment and the present one is that Rogerson and Hopenhayn have no aggregate uncertainty, and also study the entry and exit decisions of firms. Their layoff penalty then influences the capital/output ratio and thereby has aggregate effects.

	$\theta = 0$	$\theta = w$	$\theta = 2w$
Normalized average employment	1.000	1.0035	1.0095
Serial correlation of output	0.699	0.720	0.739

Table 3.2. Summary statistics

By contrast, in the present model, there is aggregate uncertainty, but no entry or exit decisions for firms. The capital/output ratio is not affected by this policy, as can be seen by noting that equation (8) is the same for all values of θ. The level of employment is affected in only the most marginal manner. To see this, one need only look to equation (9). The layoff penalty θ_t adds a cost and a reward to the left side of this equation, which reflects the effect of hiring an additional worker. This is a measure of the distortion imposed by the policy. These extra terms can be re-written as follows

$$u_1(c_t, n_t)\left[\theta_t \chi(n_{t-1} - n_t)\right] - \beta E_t\left[u_1(c_{t+1}, n_{t+1})\,\theta_{t+1}\chi(n_t - n_{t+1})\right].$$

Now it is obvious that if $\beta = 1$, this term is likely to be small in size. Since in fact $\beta = .99$, it is easy to see how the effect of this distortion would be minor.

The logic of this result can best be seen by considering a non-stochastic version of this economy, with no technology shocks. Consider starting with an initial level of the capital that is above that of the steady state. This implies that the level of employment will be below its steady-state level. The economy will converge to the steady state with capital (labor) falling (rising). Along this transition path, the optimality conditions for capital and labor are given by equations (8) and (9), where $\theta_t = 0$.

On the other hand, consider starting with an initial level of the capital stock that is below that of the steady state. This implies that the level of employment will be above its steady-state level. The economy will converge to the steady state with capital (labor) rising (falling). Along this transition path, the optimality conditions for capital and labor are given by equations (8) and (9), where $\theta_t > 0$. In particular, near the steady state, equation (9) can be written as $c = [F_2(k, n, \lambda) + \theta(1-\beta)]$. It is easy to show that since $\theta(1-\beta) > 0$, this optimization condition gives rise to a higher level of employment than if $\theta = 0$. In other words, near the steady state, since laying off workers results in a penalty there is an incentive to not lay as many of them off, and this results in a slightly higher level of employment than would otherwise be the case.

It is instructive to compare this result with that of Hopenhayn and Rogerson ([11]). In their framework, *all* firms must eventually exit the industry, thereby resulting in the eventual laying off of all workers. Consequently, there is an incentive for firms to not hire as much labor because it must all be laid off eventually. Therefore, the equilibrium level of employment in the presence of a layoff penalty is always below that which would exist if the penalty were not present.

Table 3.2 also shows that the serial correlation of output is marginally increased as θ increases. This would appear to be due to the fact that a given technology shock appears to have a smaller influence on employment, the higher is θ, and hence there is going to be smaller changes in the level of output.

4 Final Remarks

The goal of this analysis has been to investigate the effects of two policies which could be interpreted as attempts to "stabilize" the behavior of an aggregate economy. In the first economy, the choice of public investment policy, whether set in ways that one might call either 'procyclical' or 'countercyclical', turns out to have little effect on the volatility of either aggregate output or consumption, though modest stabilizations of hours and investment are possible.

In the second example, it could be seen that taxing the layoff of workers could reduce the volatility of some aggregates, such as output, consumption, investment, and employment, but it could also exacerbate these fluctuations as well. However, by construction, these policies must be welfare-reducing. It is also of interest to note the asymmetric behavior that alternative technology shocks can have on the behavior of various aggregates, since the policy imposes a nonlinearity on the resource constraint.

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5 Appendix

For clarity it is useful to assume that $\theta_t = \tau_t = 0$, although it should be clear below that a nearly identical procedure could be employed if this were not the case. Substituting equations (5) and (7) into the resource constraint (6) yields the usual aggregate condition

$$c_t + k_{t+1} \leq k_t^\alpha \left(\lambda_t n_t\right)^{1-\alpha} + (1-\delta)\,k_t. \tag{A1}$$

Now define the following "stationary" variables: $c_t^* = c_t/\lambda_t$, $k_t^* = k_t/\lambda_t$ and $x_t^* = x_t/\lambda_t$. It is then easy to show that constraint (A1) can be re-written as follows

$$c_t^* + \left(\lambda_{t+1}/\lambda_t\right) k_{t+1}^* \leq \left(k_t^*\right)^\alpha \left(n_t\right)^{1-\alpha} + (1-\delta)\,k_t^*,$$

while the utility function can also be transformed into the function

$$E_t \sum_{s=0}^{\infty} \beta^s \left[\ln\left(c_s^*\right) - \psi n_s + \ln\left(\lambda_s\right)\right].$$

The last term in the utility function can be essentially ignored since it is not influenced by any choices. Now the '*' economy is stationary since the capital stock, investment, and consumption will all grow at the same rate as the technology shock λ. Because of the stationarity of the '*' economy, it is easy to study the optimization conditions of this economy. Once the behavior of this economy is determined it is straightforward task to calculate the actual behavior of the economy by multiplying all variables by the path of λ. Also, it clear that there is no trend in the level of employment.

For this economy, the optimization conditions, given by equations (8) and (9) can be written as follows:

$$\left(\frac{1}{c_t}\right) = \beta E_t \left[\frac{F_1\left(k_{t+1}, n_{t+1}, \lambda_{t+1}\right) + (1-\delta)\,k_t}{c_{t+1}}\right], \tag{A2}$$

and

$$\left(\frac{1}{c_t}\right)\left[F_2\left(k_t, n_t, \lambda_t\right) + \theta_t \chi\left(n_{t-1} - n_t\right)\right] - \beta E_t \left[\frac{\theta_{t+1}\chi\left(n_t - n_{t+1}\right)}{c_{t+1}}\right] = \psi. \tag{A3}$$

Now a version of the finite element method is used to solve for the decision rules for this model. First the steady-state is found for the levels of the endogenous or decision variables. The important decision variables here are the capital stock and employment levels. Secondly, a finite set of points is chosen around the steady-state for the state-space of these variables. These points are chosen to be concentrated more closely to the steady-state, rather than being evenly spaced. For models without any distortions, the choice of two points is sufficient since this implies linear decision rules, which is the standard manner in which many dynamic models are solved. Choosing more points merely allows for more "non-linearity" in the decision rules. Thirdly, the optimal decision rules are calculated from repeatedly iterating on equations (A2) and (A3) as follows. First an initial guess is made for the optimal decision rules at each point in the state space. Then, a new decision rule is calculated, assuming that all future behavior is determined by the previous iteration, and by employing an interpolation routine so that an agent's decisions are not restricted to lie in the same grid on every iteration. The procedure is terminated when the decision rules have converged, which can be relatively quick on a Pentium machine.

The actual solution of the model is impeded by the fact that at each iteration, and at each point in the state space, the optimization condition (A3) must be structured to take into account whether the variable χ is positive or not. In particular, as equation (A3) indicates, the choice of employment n_t must take into account the term involving $\chi(n_{t-1} - n_t)$ and that involving the expected value of $\chi(n_t - n_{t+1})$. By taking these effects into account, the solution of the model takes somewhat longer than it would otherwise.

The time-series for the model were generated as follows. First, the decision rules for the stationary or '*' economy were obtained. Secondly, the non-stationary behavior of all the aggregates was obtained by "adding back in the trend", as produced by the time-series for λ. Then the resulting series were detrended using the Hodrick-Prescott filter.

Figure 1

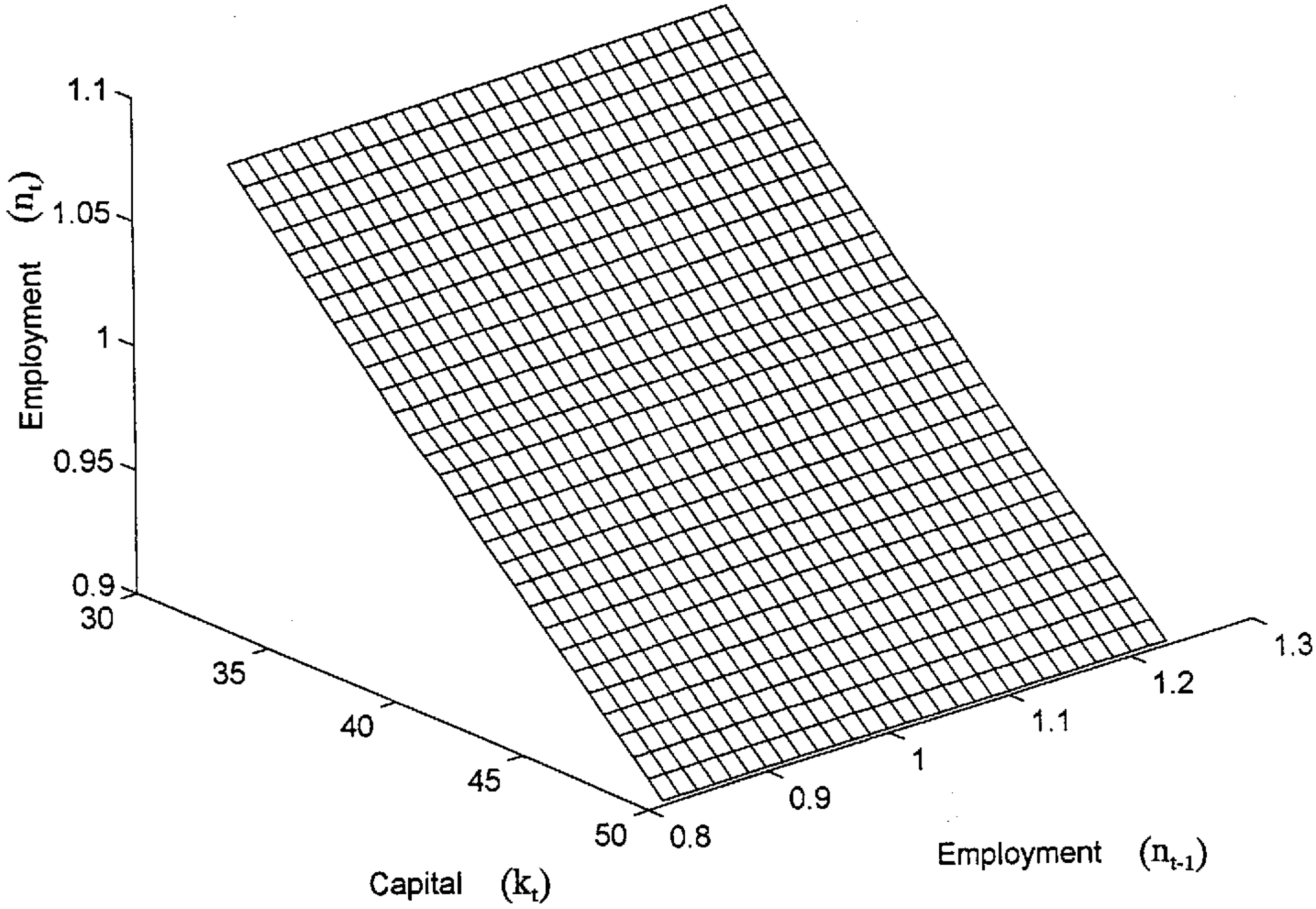
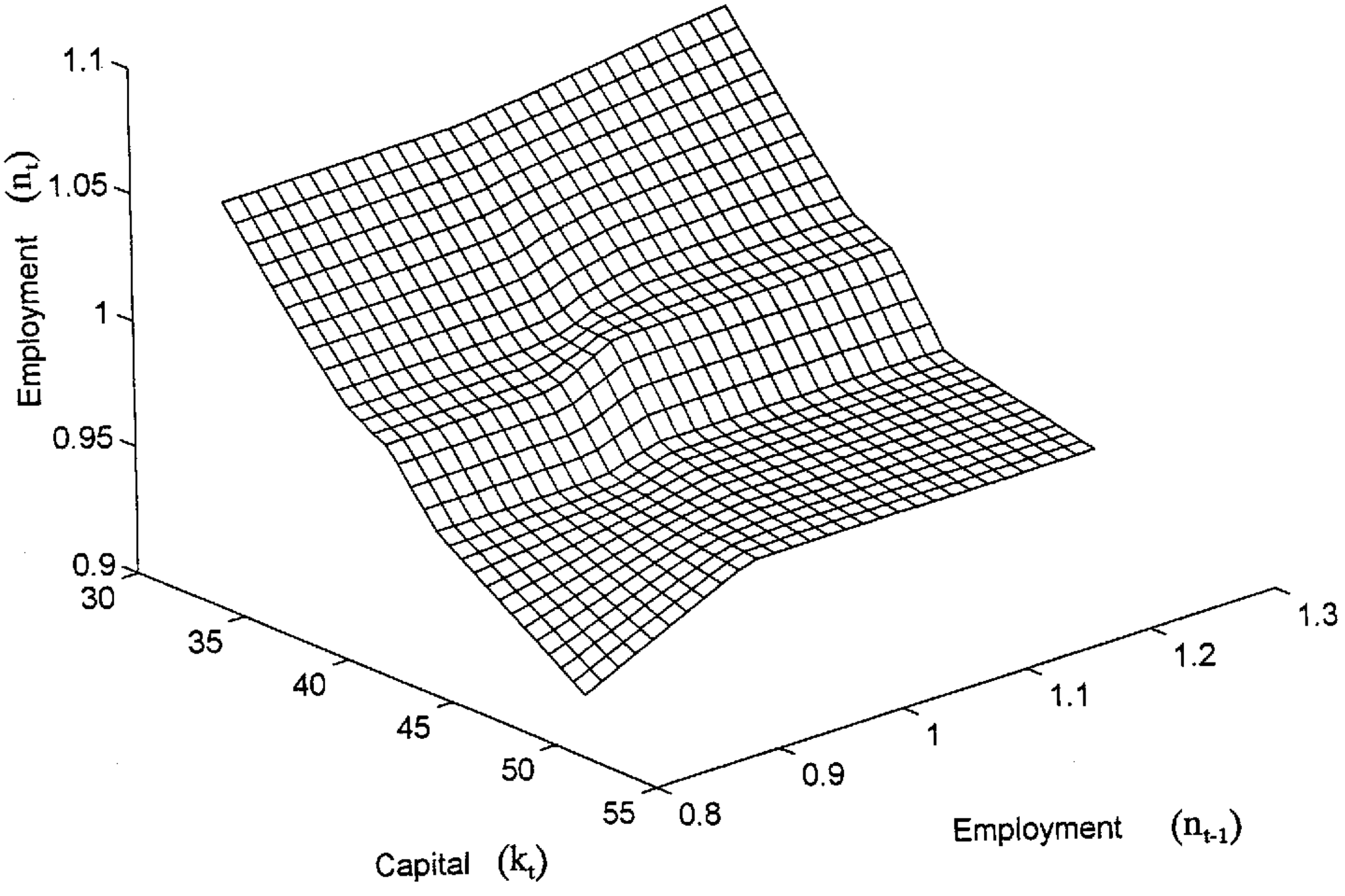

1.1
1.05
1
0.95
0.9
Employment (n_t)
30
35
40
45
50
Capital (k_t)
0.8
0.9
1
1.1
1.2
1.3
Employment (n_{t-1})

Figure 2


1.1
1.05
1
0.95
0.9
Employment (n_t)
30
35
40
45
50
55
Capital (k_t)
0.8
0.9
1
1.1
1.2
1.3
Employment (n_{t-1})

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