THE ROLE OF INTRATEMPORAL ADJUSTMENT COSTS IN A MULTI-SECTOR ECONOMY

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The Role of Intratemporal Adjustment Costs in a Multi-Sector Economy[1]

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ABSTRACT

A multi-sector business cycle model is constructed which is capable of reproducing the procyclical behavior of cross-industry measures of capital, employment, and output. It is shown that some variants of conventional business cycle models may not be capable of reproducing these facts. It is then shown how the introduction of *intratemporal* adjustment costs can be crucial to such a model. These costs imply that it is difficult or costly to alter the composition of the capital goods that are produced. The presence of these costs eliminates many counterfactual observations of the model that would otherwise be present. The dynamic response of variables in the model is different from what one would observe in the standard one-sector model. The effect of including intratemporal adjustment costs for labor as well is also analyzed.

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I Introduction

Modern dynamic general equilibrium models of the business cycle were developed to better understand and explain certain aggregate cyclical observations[1], but to date there has been relatively little research using these models to explain the cyclical behavior of investment, capital, employment and output across industries. Much of the focus of the business cycle literature is on the behavior of aggregate hours, and the causes and consequences of movements in this variable. It seems only natural to also explore the cyclical behavior of sectoral movements in factors of production and output. Most existing models are reticent on this issue and, as will be shown below, possibly for good reason. This paper addresses the issue of sectoral movements in inputs and outputs by constructing and analyzing a simple model that is capable of speaking to these issues. We show how the standard business cycle framework can be augmented to produce a multi-sector model whose behavior is consistent with many features of the postwar U.S. data.

A defining characteristic of business cycles, whether in the traditional sense of Burns and Mitchell (1946), or in the contemporary sense of Lucas (1977), is the co-movement in the pace of economic activity in *different sectors of the economy*. Burns and Mitchell (1946) emphasized this co-movement in their definition of the business cycle.[2] Lucas (1977) notes that it is the co-movement of economic activity across different sectors of the economy is the most important of the regularities that are common to all business cycles and that it is this co-movement that creates the potential for a single unified theory of business cycles.[3] Thus, it is puzzling that so much of the general equilibrium business cycle literature has tended to ignore this feature when analyzing whether certain models are consistent with certain business cycle observations.

As will be shown below, the actual levels of investment and employment in various sectors of the economy do not move perfectly in tandem. However, it also true that almost all of these variables move in a procyclical manner. Although one might suspect that this is an easily explainable observation, as will be shown below, it is not straightforward to produce a variant of a real business cycle model which is capable of reproducing this fact. Furthermore, replicating this feature would seem to be a necessary first step in producing a disaggregated real business cycle model that is capable of analyzing the sectoral movements in factors of production and output.

In fact, one of the motivations for the work of Benhabib, Rogerson, and Wright (1991) was that within a standard business cycle model (specifically, that of Hansen (1985)), employment in the consumption-good producing sector is strongly countercyclical. They argue that this is contradicted by the fact that employment in virtually all sectors appears to be procyclical. However, their model is not a multi-sector model in the sense employed here, since their *second sector* is home production, and obviously some nontrivial fraction of the labor "employed" in this sector could reasonably be interpreted as leisure.[4] Hence employment in one of their sectors must necessarily be countercyclical. Furthermore, although their introduction of home production reduces the strong negative correlation of employment in the consumption sector and aggregate output, this correlation is not strongly positive. Additionally, they do not address the issue of the sectoral behavior of investment. Greenwood and Hercowitz (1991) study a model in which there is *investment* in both home and market production, but again they only have one market sector, and consequently do not speak to the issues addressed here.[5]

A central assumption in what follows is that it is *costly* to alter the composition of capital goods produced in an economy. Consider an economy composed of many different market sectors which have different technologies for producing different goods and services. Examples of these sectors might be construction, manufacturing, farming, mining, services, and so on. Now consider a technological innovation which occurs in, say, the manufacturing sector that leads to higher productivity of the factors employed therein. Other things being equal, this would likely lead to increased investment and employment in this sector and to increased output in subsequent periods. It is unlikely, however, that a significant quantity of *existing* capital would move from the other sectors to employment in the "high productivity" sector. In particular, it is doubtful that tractors used in farming, equipment in restaurants, or drilling equipment in mines, could be rapidly moved into production in the manufacturing sector to take advantage of favorable production opportunities in that sector. More importantly, it seems equally implausible that the processes that *produce* these capital goods could be easily changed to produce a different mix of new capital goods in response to the shock. That is, the factors of production that help produce computers cannot easily or quickly be converted into the equipment and skilled labor needed to produce heavy construction equipment. In other words, within a period there might be plenty of capital, or even labor, which is *sector-specific*. Higher demand for, say, capital in one sector does not give rise to the rapid movement of capital from other sectors. What we are proposing is somewhat different, namely a cost of re-orienting the *production* of new capital goods from producing for one sector to producing for another. This feature of an economy might well be termed the *intratemporal adjustment costs* of the factors of production. Furthermore, it seems that there might also be such costs associated with reallocating labor from one sector to another.

It is worth asking at the outset why it is necessary to construct a multi-sector model of the business cycle, given that it is possible to understand much of the cyclical nature of market economies within a highly aggregated framework. The answer must be that by understanding the cross-sectoral movements in inputs and outputs that take place at business cycle frequencies, we will enhance our understanding of the causes and effects of cyclical fluctuations. For example, one might have more confidence in these general equilibrium models if they were shown to be consistent with the sectoral movements in employment as observed by, say, Lilien (1982), and studied by Loungani and Rogerson (1989). Ultimately, it would be of interest to know how technological innovations or government policies influence the allocation of factors of production across sectors. It is likely the case that certain distortional government policies can influence the amount of capital and labor employed in various sectors. Investment tax credits or capital taxation will have different impacts on the amount of capital employed in various sectors, depending on how important capital is in the production process. It is not obvious how government policies will influence the allocation of factors of production in various sectors, and therefore influence the cyclical behavior of an economy. The older monetary business cycle literature addressed the question of how shocks to monetary policy affect different sectors of the economy (see Kretzmer (1989)). It would be interesting to see if the stylized facts uncovered in that literature could also be accounted for by a dynamic general equilibrium model driven by technological shocks. Yet another reason it is of interest to study a disaggregated model is that some sectoral data is useful for other purposes. For example, the Commerce Department's index of leading indicators includes many *industry-specific variables* such as manufacturers unfilled orders, permits for housing units, contracts for plant and equipment, manufacturers new orders, and weekly hours of production in manufacturing. Presumably, a better understanding of the business cycle would be gained by studying models in which these same variables were leading indicators as well. Finally, it seems likely that it will be necessary to move to a multi-sectoral framework if unemployment is to be introduced in a meaningful manner into general equilibrium models of the business cycle.[6]

The analysis below complements that of Hornstein and Praschnik (1994) who are also interested in understanding the co-movement of output, employment, and investment in a multi-sector setting. Hornstein and Praschnik study a simple two-sector model. The key difference between their analysis and that presented below is in the mechanism used to induce co-movement. In their setup, the output of one sector is used as an intermediate input in the other sector. Specifically, they argue that the use of the output of the nondurable goods sector as an intermediate input in the production of durable goods is the key to generating plausible co-movement of output, employment and investment across the two sectors. This is tantamount to assuming that all sectors produce capital goods, with some capital goods being longer-lived than others. In our model, co-movement comes about as a result of joint production in one sector and limited possibilities for switching between producing the two types of capital. In our model, only one sector produces capital or investment goods for future use in both industries.

The issue of sectoral co-movement was explicitly addressed in one of the earliest papers in the real business cycle literature, namely Long and Plosser (1983). They develop a simple model aimed at demonstrating the possibility of a sectoral co-movement in output similar to that characterizing the business cycle. The output of each sector can be used as in input in the production of all other goods. However, as a result of the particular specification of tastes and technology that they utilize, employment in each sector is independent of current realizations of the technology shock and is *constant* over the cycle. It will be shown below that a variant of their model is unlikely to give rise to cross-industry business cycle behavior that resembles that observed in the data.

The remainder of this paper is organized as follows. In the next section, some of the cross-industry features of the U.S. data are described to illustrate the procyclical nature of the inputs and outputs of various industries. In Section III the physical environment is described, starting with a counterfactual economy that does not have intratemporal adjustment costs, and which is not capable of mimicking many of the observed cross-industry features of the U.S.

economy. Intratemporal adjustment costs are introduced and it is shown how the behavior of the model is much more in accord with that of the U.S. data. Next, it is shown how various variables move in reaction to technological innovations in the various industries. Final remarks and conclusions are presented in Section IV.

II Stylized Facts about Sectoral Activity.

It is important to begin by documenting some of the facts about the cyclical behavior of the economy across different sectors so that it is possible to have a benchmark against which to measure the performance of the model economy. Some basic facts about sectoral economic activity are presented in Tables 1-21. A major hindrance to a comprehensive investigation of sectoral business cycles is the paucity of data that is available at a monthly or quarterly frequency for the U.S. economy. At a quarterly frequency only data on the labor input (measured either in terms of hours or number of employees) is available.

Table 1 presents the correlation of (Hodrick-Prescott-filtered) employment in each of the eight major sectors of the U.S. economy with (HP-filtered) aggregate output at various leads and lags.[7] Table 2 presents the same correlations for hours worked in each of the eight sectors. Not surprisingly, the labor input in almost every sector is strongly procyclical, with the interesting exception of mining. The labor input in mining tends to be slightly countercyclical: high levels of aggregate activity relative to trend tend to be associated with low levels of employment in mining relative to trend. This negative correlation no doubt reflects the fact that the mining category includes the oil drilling activities of the oil industry. The labor input in most sectors tends to lag the cycle slightly, in the sense that the one quarter lead of the labor input tends to have the highest correlation with output. A number of other points are also worth noting in Tables 1 and 2. There are sizable differences in the degree to which the labor input in different sectors moves with the cycle. The countercyclical behavior of the labor input in mining has already been noted. As for the other seven sectors, note that the (contemporaneous) correlation of employment with aggregate output ranges from a low of 0.45 in the financial services industry to a high of 0.86 in retailing. The peak correlation with aggregate output is with employment in manufacturing with a lead of one quarter. In terms of hours, table 2 shows that hours worked in manufacturing tend to move with the cycle contemporaneously, while hours in services tend to lag the cycle (with the peak correlation with aggregate output coming at 3 leads).

As for the volatility of the labor input across industries, employment in construction is almost five times as volatile (as measured by its percentage standard deviation) as employment in services. Indeed, employment in goods-producing industries is systematically more volatile than employment in service-producing industries. Much the same pattern is evident when the pattern of hours is studied: again, hours in mining and construction are more than five times more volatile than hours in services.

The model studied below will have only two sectors so it is necessary to combine the sectoral data into broader aggregates that correspond in some sense to the sectors in our model. The sectors in the model produce durable and non-durable goods respectively, which correspond to consumption and investment goods. The latter are long-lived and are used as capital inputs in each sector's production process, while the former are nonstorable and enter only into consumers' utility functions. To decide whether a sector belonged in the durable or nondurable category, the 1987 Input-Output tables (see Lawson and Teske (1994)) were studied to determine how much of each industry's final output went to consumption as opposed to investment or intermediate uses. If the bulk of an industry's final output is allocated to meet final consumption demand it is classified as a non-durable producing, or consumption-type, industry; if the bulk of an industry's output is allocated to investment or intermediate demand, the industry is classified as a durable producing, or investment-type, industry. Using this criterion, the mining, construction, manufacturing, transportation and public utilities and wholesale trade industries are grouped into the investment or durables category (Group 2), and finance insurance and real estate, retail trade and services industries are grouped into the nondurables or consumption category (Group 1).

Tables 1 and 2 also present the correlations of employment and hours in each of these two broader categories with aggregate output. Note that the labor input in the durables sector tends to be more strongly correlated with aggregate activity than the labor input in the nondurables sector, in addition to being a lot more volatile that the labor input in the nondurables sector. Note also that the sum of the labor input in the eight sectors (reported in the column headed "Total") has a stronger contemporaneous correlation with aggregate output than do any of the sectors considered individually. This might seem a little strange at first - one might suspect that the correlation of the sum should in some sense be some sort of average of the correlations of the individual sectors. However, once it is borne in mind that each of the series is detrended with its own filter, it is no longer clear that one should expect this intuition to hold.

As has already been noted, it is only possible to obtain data on the labor input at a quarterly frequency: data on output, productivity and capital stocks are only available at an annual frequency. Table 3 presents correlations of output in each sector with aggregate output at various leads and lags. It is noteworthy that the contemporaneous correlation of manufacturing output with aggregate output is a little bit less than three times as big as the correlation of financial sector output with GDP.[8] In none of the sectors does output show a systematic tendency to lead or lag the aggregate cycle. As for volatility, output in manufacturing is the most volatile, while output in FIRE is the least volatile. Aggregating sectors, it is seen that durables sector output is more correlated with aggregate output than nondurables output, and is also nearly three times more volatile.

Tables 4-6 present the correlations between capital in each industry and aggregate output, where the capital stock is measured as the net stock of capital in each industry measured in 1987 dollars (see US Department of Commerce 1993a). There is a clear tendency for the total capital stock to lag the cycle in the construction, manufacturing and transportation industries. In the wholesale, retail, FIRE and (to a lesser extent) services industries the capital stock tends to move more contemporaneously with aggregate activity. Note that the capital stock in the consumption-type industries is more volatile than the capital stock in the investment-type industries. These patterns seem to reflect primarily differences in the cyclical behavior of the stock of equipment in the different industries, as shown in Table 5. For example, there is a strong contemporaneous movement of the stock of equipment in retailing, and essentially no cyclical movement in the stock of structures in that sector. The stock of equipment in the consumption-type moves contemporaneously with activity, while that in the investment-type aggregate lags by a year.

Table 7 presents correlations between Solow residuals for each sector and aggregate output. The measured Solow residual for each industry is written as

$$\log(z_{i,t}) = \log(y_{i,t}) - \alpha_i \log(k_{i,t}) - (1-\alpha_i)\log(n_{i,t})$$

where labor's share in income $(1-\alpha_i)$, is defined as the ratio of the sum of compensation of employees plus proprietors income to GDP in the i'th sector, averaged over the period 1948-1992. Output in each sector, $y_{i,t}$, is measured as GDP in 1987 dollars produced in that sector. The labor input in each sector, $n_{i,t}$ is measured as the number of full time equivalent employees in the sector, while the capital employed in the i'th sector during period t, $k_{i,t}$, is measured as the net stock of capital outstanding (in 1987 dollars) in that sector at the end of the previous year. The strongest correlation between a sectoral Solow residual and aggregate output is for the manufacturing sector. In terms of the relative volatilities of the shocks hitting different sectors, the Solow residuals for the investment-goods producing industries are more than twice as volatile as the residuals for the consumption-goods producing industries.

Table 8 presents similar data to that in Table 7 for labor productivity in each industry, with labor productivity defined as GDP per hour worked. Again the highest contemporaneous correlation between sectoral productivity and aggregate output is for the manufacturing sector. Note also that productivity in this sector seems to lead the cycle by about a year. Similar lead type patterns are observed in the mining, construction (by two years), transportation, wholesale and retail industries. The lead pattern is also apparent in the aggregated sectors, and is strongest for the durables industries. Another anomalous feature of the behavior of labor productivity in different sectors is the apparent countercyclical behavior of productivity in the financial sector. Finally, labor productivity appears to be much more volatile in the durable industries than in the nondurable industries.

The next three tables document the cyclical properties of investment flows in the different sectors. Table 9 reports the correlation of sectoral investment flows with aggregate output at an annual frequency. Again there are some striking differences in the behavior of investment in each sector over the cycle. Investment in mining has essentially no correlation with aggregate output contemporaneously, while investment in the construction, services and transportation industries is highly correlated with output contemporaneously. Investment in manufacturing is less strongly correlated with aggregate output contemporaneously: in fact investment in the manufacturing sector lags the cycle slightly. Manufacturing is the only sector that exhibits this tendency for investment to lag slightly: note that this lag pattern is not apparent in the total, nor in the investment-goods producing aggregate which includes manufacturing. Investment in the mining and construction sectors (which are the most volatile) is almost twice as volatile as investment in the service sector (which is the least volatile).

Tables 10 and 11 break investment down into equipment and structures. In general, equipment investment is much more procyclical than structures investment. In some sectors (mining, retail, and services) structures investment is actually slightly countercyclical. This countercyclical pattern is apparent at all leads and lags for structures investment in the services industry. Both types of investment tend to lag the cycle in manufacturing. For transportation, equipment investment is strongly procyclical, while investment in structures tends to lag the cycle. Finally, note that there is a lot more volatility in the aggregates for structures investment than there is for equipment investment, and that the investment flows are lot more volatile for the consumption goods aggregate than for the investment goods aggregate.

While we are restricted to looking at annual data for sectoral investment flows, we can get additional information about the cyclical behavior of investment by examining quarterly data for aggregate investment. From Table 12 we see that various measures of quarterly investment are strongly procyclical, with residential investment tending to lead the cycle by about two quarters, while business investment tends to move more in line with aggregate activity.[9] Interestingly, business investment in structures tends to *lag* the cycle by about two quarters. Note also that residential investment is a lot more volatile than investment in other structures or investment in producers durable equipment. Thus the cyclical patterns we observe in the sectoral data at an annual frequency (some tendency of structures investment to lag the cycle while investment in equipment tends to move contemporaneously) is borne out in the aggregate data at a quarterly frequency.

Tables 13-15 present the correlation of the deflators for different measures of investment by industry with aggregate output, with prices measured in units of 1987 output. The most striking feature of these tables is the strong countercyclical behavior of all of the price series. Note that the countercyclical pattern is stronger for the investment-goods producing industries than for the consumption-goods producing industries. There is also a stronger countercyclical pattern for the equipment deflator than for the structures deflator.

Tables 16-18 present the same correlations for investment prices as in Tables 13-15, except that investment prices are now measured in terms of consumption goods. The motivation for considering this alternative measure is that in the models considered below, all prices will be measured in terms of consumption goods. Note that the prices of all investment goods for consumption-goods producing industries go from being countercyclical to moderately procyclical. The change is most pronounced for structures purchases in these industries. There is also a more pronounced tendency for the prices of structures investment to lag the cycle when measured in consumption units.

Tables 19-21 report correlations of various leads and lags of real wages and rates of return in the different sectors with aggregate activity. Table 19 reports the correlations of real wages (defined as the nominal hourly wage multiplied by the number of hours worked per quarter, divided by the number of employees and deflated by the GDP deflator) by industry. The results here are among the most striking of any in the series studied. Note the almost total absence of a cyclical pattern in the real wage in the construction sector, as against the strong procyclical patterns observed in manufacturing, transportation, wholesale and retail. The procyclical pattern is strongest in the investment-goods producing aggregate: this aggregate is also more volatile than real wages in the consumption-goods producing aggregate. Interestingly, the construction sector, which exhibits the weakest cyclical pattern also exhibits the greatest volatility. Finally note that real wages in the consumption-goods producing industries tend to lead the cycle by about two quarters.

Tables 20 and 21 present the correlations of quarterly nominal and real stock returns by sector with aggregate activity. The dominant feature of these correlations is the uniformly countercyclical behavior of returns whether measured in real or nominal terms. What is also striking is how close most of the contemporaneous correlations (for both the nominal and real returns) are to -0.30. The exceptions are the mining and construction industries. However, the volatility properties of these returns vary a great deal across industries, with mining, construction, wholesale and services returns being more variable than those of transportation or manufacturing.

Finally, Table 22 presents summary statistics on the behavior of the major macroeconomic variables. We will refer back to this table in comparing the performance of different multi-sector models below.

Thus an analysis of even relatively aggregated sectoral data reveals patterns of correlation with aggregate output that are not apparent from the aggregates that are the typical focus of business cycle analyses. There is an interesting story to be told about what is going on at the sectoral level. In the next section of the paper a simple two sector model is examined for its ability to account for some of the stylized facts listed above.

III The Physical Environment

The economic environment to be studied will be a simple two-sector model, which could be easily and obviously extended to a more complicated environment. In many ways, the structure is quite similar to that described by Hansen (1985). The first sector produces a perishable consumption good from capital and labor. The production technology for this sector will be written as $c_t = f(k_{1,t}, \lambda_{1,t} n_{1,t})$. Here c_t refers to consumption in period t, while $k_{1,t}$ and $n_{1,t}$ refer to capital and labor employed in the same period t respectively. Additionally $\lambda_{1,t}$ is a random productivity disturbance which is assumed to be generated by some stochastic process to be specified below. For the most part this production technology will be assumed to take the specific functional form[10]

$$f(k_{1,t}, \lambda_{1,t} n_{1,t}) = [\alpha_1 k_{1,t}^{-\nu} + (1-\alpha)(\lambda_{1,t} n_{1,t})^{-\nu}]^{-1/\nu} \tag{1}$$

where $\alpha_1 \in (0,1)$ and $\nu > -1$.

The second sector produces a durable investment good from capital, $k_{2,t}$, and labor, $n_{2,t}$, employed in that sector. There will also be a random technology shock $\lambda_{2,t}$ to this production process. We will assume that the technology for the second sector has the familiar Cobb-Douglas functional form. The resource constraint for the second sector can be written in the following form

$$\phi i_{1,t} + (1-\phi) i_{2,t} = k_{2,t}^{\alpha_2} (\lambda_{2,t} n_{2,t}^{1-\alpha_2}) \tag{2}$$

where $i_{1,t}$ and $i_{2,t}$ represent investment in the two sectors respectively, and α_2, $\phi \in (0,1)$

are constants. With $\phi = 0.5$, this results in the standard resource constraint for the capital goods producing sector in a two-sector model. Here ϕ should be interpreted as influencing the relative price of the two investment goods. That is, one unit of $i_{1,t}$ is equivalent to $\phi/(1-\phi)$ units of $i_{2,t}$. However, the main focus of this paper will instead be the following technology, of which equation (2) is a special case:

$$[\phi i_{1,t}^{-\rho} + (1-\phi) i_{2,t}^{-\rho}]^{-1/\rho} = k_{2,t}^{\alpha_2} (\lambda_{2,t} n_{2,t})^{1-\alpha_2} \tag{3}$$

where $\rho \leq -1$.

The left side of equation (3) might be interpreted as a "reverse CES" technology since the typical CES technology would be restricted to have $\rho > -1$. Figure 1 illustrates this relationship by plotting the graph of the equation $i_{1,t}^{-\rho} + i_{2,t}^{-\rho} = 1$.[11] As illustrated in Figure 1, the restriction $\rho \leq -1$ makes the "isoquants" concave to the origin, and is necessary for the production possibilities set to be convex.[12] This modification is important for the following reason. For $\rho = -1$, there is an infinite elasticity of substitution between $i_{1,t}$ and $i_{2,t}$. This implies that it is very easy to switch from the production of one type of capital good into that of another. Specifically, by cutting back on the production of new capital goods for one sector by one unit it is possible to increase production of new capital goods for the other sector by one unit without any need to increase overall production of new capital goods. It is plausible that an economy can alter its capacity for producing heavy capital equipment on the one hand, and alternative capital goods that could be used to produce services or consumer non-durables, on the other hand. However, it can be costly to do so quickly. As illustrated in Figure 1, as the absolute value of ρ gets bigger, it becomes more difficult to alter the composition of capital goods produced. As ρ approaches infinity, it is impossible to alter the composition of the production of these investment goods. In other words, there is an infinite cost of doing so, and consequently the two capital stocks will be perfectly correlated.

The feature shown in equation (3) and illustrated in Figure 1 can be interpreted as *intratemporal adjustment costs*, since it refers to the decreasing marginal returns encountered in producing more of one type of investment good while reducing the production of the alternative investment good at a particular moment in time. This stands in contrast to the traditional *intertemporal* adjustment costs in which there are decreasing returns to giving up some of the consumption good, which may be perfectly substitutable with existing capital, in one period so as to increase the future capital stock.[13] Another feature of having capital goods produced in a distinct industry is that there is an *endogenous* price for each type of capital. Greenwood, Hercowitz and Huffman (1988) show how exogenous shocks to the relative price of capital can be an important ingredient in business cycle fluctuations.

It will also be assumed that capital is not substitutable across sectors. The idea here is that capital used in the production of heavy industrial equipment cannot easily be used also produce food or entertainment. This assumption is captured by assuming that there are two separate accumulation equations for the capital stocks in each sector:

$$k_{j,t+1} = (1-\delta_j)k_{j,t} + i_{j,t}, \qquad for\ j=1,2 \tag{4}$$

where δ_j denotes the rate of depreciation of capital in sector j.

The technology shocks are assumed to obey the following law of motion:

$$\Lambda_t \equiv \begin{bmatrix} \log(\lambda_{1,t}) \\ \log(\lambda_{2,t}) \end{bmatrix} = \Gamma\Lambda_{t-1} + \epsilon_t$$

The matrix Γ will be described below. Of course, if the off-diagonal elements of Γ are positive, this would make the technological disturbances in the two sectors move together, and therefore be more likely to make production in the two sectors move together on average. Here $\epsilon_t \equiv [\epsilon_{1,t}\ \ \epsilon_{2,t}]^T$ is a zero mean two-dimensional vector of normally distributed random variables, with variance/covariance matrix Σ .

The consumers populating the economy have the standard type of time-separable preferences, which are described as follows

$$E\left[\sum_{t=1}^{\infty} \beta^t U(c_t, T-n_{1,t}-n_{2,t})\right]. \tag{5}$$

where T is the total time endowment. The utility function is increasing in its two arguments, consumption and leisure. The point-in-time utility function will be assumed to be of the following form

$$U(c_t, 1 - n_{1,t} - n_{2,t}) = \log(c_t) + (T - n_{1,t} - n_{2,t}) \qquad (6)$$

Preferences are assumed to be linear in leisure for the reasons described in Hansen (1985), although this not a necessary assumption. Note that this specification of the point-in-time utility function belongs to the class of utility functions identified by King, Plosser and Rebelo (1988) as consistent with balanced growth.

Before proceeding to examine the behavior of this model, it should be noted that the presence of multiple sectors gives rise to a subtle measurement issue. The most natural manner to measure aggregate output is to add the amount of the consumption good produced to the amount of the investment good produced, where the latter is measured in consumption units using the (contemporaneous) relative price of capital goods. The problem with this approach is that this is not the manner in which actual national accounts are constructed. Instead, a fixed-weight price deflator is employed to add the amount of investment to that of consumption. Obviously, this does not allow for relative price changes on a period-by-period basis. Thus, to make the comparisons of the model with actual data as careful and informative as possible, aggregate output will be measured in a similar manner to the national accounts method, with the fixed-weights used in calculating investment being the relative price of investment in the non-stochastic steady-state.

The length of a time period in the model is assumed to be a quarter. As noted in Section II, there is some data on cross-industry data on employment, output, investment, and the technological shocks. This quarterly data could be time-aggregated in order to scrutinize its "annual" behavior. However, there is then the danger that some industry aggregates would be procyclical on a annual basis, but not at quarterly basis. Since the quarterly data presented in the previous section was almost all procyclical, it is important to begin with a model that could potentially explain these observations.

As mentioned in Section II, we will take the structure of the economy seriously in the sense that the durable or investment-type goods sector will produce investment goods for both sectors, while the nondurable or consumption-type goods sector produces the consumption good.

Thus the empirical counterpart of the consumption-type goods industry will consist of the retail, services, finance, insurance and real estate sectors (corresponding to the definition in section II above). The investment-type goods industry will then consist of mining, construction, manufacturing, transportation, and public utilities, and wholesale trade. Using these classifications, the four key parameters of the production technologies can be calculated using standard assumptions. Specifically, the elasticity of output with respect to the labor input in each sector $(1 - \alpha_j)$ is calculated as the average value over the postwar period of the ratio of the sum of compensation of employees plus proprietors income to output in each sector. This yields the following estimates: $\alpha_1 = .41$, $\alpha_2 = .34$. To calculate rates of depreciation in each sector, the ratio of annual depreciation to net capital stock (as reported in US Department of Commerce 1993a) in each sector is calculated, to obtain: $\delta_1 = .018$, $\delta_2 = .021$. The value for T is chosen so that households worked between one-fifth and one-third of their time endowment in steady state equilibrium. The parameter ϕ is chosen so that the price of each type of capital in each industry, measured in units of the consumption, is equal in the non-stochastic steady-state. Therefore $\phi = .5$ if $\rho = -1.00$, and $\phi = .4398$ if $\rho = -1.20$. Additionally, it will be assumed that $\beta = .99$, since a period in the model will be taken to be a quarter.

The data on the technological disturbances can be used to derive the parameters of the law of motion for the productivity disturbances as follows[14]

$$\Gamma = \begin{bmatrix} 0.75 & 0.00 \\ 0.00 & 0.87 \end{bmatrix}, \qquad \Sigma = \begin{bmatrix} .00918 & .00406 \\ .00406 & .01877 \end{bmatrix}. \tag{7}$$

These are the settings for the exogenous stochastic processes that are then used below. As can be seen the technology shocks in the investment-goods producing industry exhibit more volatility than do those in the consumption-goods producing industry.

A Specific Example

As the focus of this analysis is on how intratemporal adjustment costs can further our understanding of business cycles in multi-sector environments, much of the remainder of the model will be standard. In particular there will be no role for government, externalities, or monetary issues. Therefore, the allocations that will be studied will be the optimal ones derived from the solution to the social planning problem. The model is solved in a usual manner by substituting equations (1), (2), (4),and (6) into the objective function, as given by equation (5), and taking a quadratic approximation around the steady-state. This is then used to produce (log) linear decision rules for the investment and employment decisions.

Tables 23 and 24 give some idea of the behavior of the model without adjustment costs.[15] There are several things to note from these tables, which illustrate the counterfactual behavior of the model. First, consumption is strongly countercyclical, while aggregate investment is nearly perfectly correlated with output. Secondly, the value of investment in both industries is *much* too volatile.[16] This is attributable to the high degree of substitutability of investment between the two sectors, as illustrated in Figure 1. Other flaws in this model are the countercyclical behavior of aggregate labor productivity (denoted by π), investment in the second industry, as well as capital and labor productivity in the first sector (denoted by π_1). Capital in the second industry is much too procyclical and too volatile, and employment in second industry is also too volatile.

The intuition for why inputs and outputs in sector 2 (the durable or investment-goods producing sector) are more procyclical than those in sector 1 (the nondurable or consumption-goods producing sector) is as follows. In the event of a favorable productivity shock in the capital goods producing sector, labor and capital will be attracted to this sector and thus movements in aggregate activity will be dominated by what is happening is this sector. In the event of a favorable productivity shock to the consumption-goods producing sector, labor and capital will be attracted to that sector, but this reallocation of factors will be tempered by the fact that the favorable production opportunities can only be propagated forward in time by increasing production of capital goods. This will become more apparent below.

Table 24 also shows many other peculiar features of this baseline model, such as the fact that output, investment, and capital stocks in the two industries are nearly perfectly negatively correlated. Labor productivity in the two industries is also negatively correlated. Still other counterfactual predictions of this model not illustrated in the tables is the fact that the real price of capital across industries is identical (see Appendix B). Consequently, the correlation of the real rate of return to capital in the alternative industries is 0.999. One does not have to observe asset markets for very long to realize that this does not appear to reflect the behavior of actual rates of return in different industries (see, for example, Ferson and Harvey (1991)). In the data the correlation between the quarterly real rates of return in the nondurables and durables industries is 0.931 for stocks listed on the NYSE from 1949 to 1994. In summation, it is easy to see that many of the variables in this model display behavior that is wildly at odds with the data as displayed in tables 1 through 21.

To better understand the behavior of this model, Figure 2 describes the behavior of the various variables in response to a one standard deviation shock to ϵ_2 at date $t=1$. Aggregate output and consumption output fall immediately, while investment rises. The reason is that since λ_2 has increased, i_2 (and subsequently k_2) will increase to take advantage of the increased productivity in the second sector. As λ_2 subsequently reverts to its normal level, so too do i_2 and k_2. Since i_2 has increased so much, i_1 will fall immediately upon the rise in ϵ_2, and consequently consumption falls. Because consumption falls, agents substitute leisure for consumption, and so employment falls. As more capital goods are accumulated, k_1 grows and k_2 falls as agents wish to increase their consumption.

The economics behind this example is as follows. Since new capital goods and labor are substitutable between industries and perfectly mobile, there is a natural tendency for both factors to move (immediately!) to where their marginal products are highest. If the marginal product of capital in the investment-goods producing industry rises, there is a strong incentive to reallocate capital to that sector from the consumption-goods producing sector. However, since it is assumed that capital already in place is immobile, the incentive to reallocate capital will only affect the allocation of new capital goods. Specifically, investment in the investment-goods producing industry will be increased at the cost of reduced investment in the consumption-goods producing industry. Since there is an infinite elasticity of substitution between the two types of investment goods (see equation (2)), this reallocation is feasible. Similarly, there is also an infinite elasticity of substitution between leisure and labor, as well as between labor in the two industries, so there is even more reason for rapid movement of labor to where its societal marginal product is highest.[17]

Before proceeding, it is worth asking whether the addition of *inter*temporal adjustment costs for capital can improve the performance of this baseline model. That is, the left side of equation (2) could be changed from $\phi i_{1,t} + (1 - \phi) i_{2,t}$, to something like the following:

$$\phi[i_{1,t} + (k_{1,t+1} - k_{1,t})^2] + (1 - \phi)[i_{2,t} + (k_{2,t+1} - k_{2,t})^2] = k_{2,t}^{\alpha_2}(\lambda_{2,t} n_{2,t})^{1-\alpha_2}$$

This is a straightforward modification of the standard specification of intertemporal adjustment costs where more rapid adjustment of the capital stock over time requires greater inputs of new capital goods. This does not work because, although this modification slows the movement of capital from industry to industry, it does not alter the *direction* of the desired movements. That is, with intertemporal adjustment costs, the capital movements are smaller in response to a technological innovation in the investment-goods producing industry, but there is still a tendency for capital in this industry to be strongly procyclical, and for the reverse to be true for capital in the consumption-goods producing industry.[18] This behavior is not particularly sensitive to the parameter settings or to the specified behavior of the exogenous productivity disturbances.

These results motivate the study of an alternative economy in which $\rho < -1$. In particular, consider an economy that is identical in every respect to the one presented above, except that now it is assumed that $\rho = -1.2$. As shown in Figure 1, this does not introduce an *extreme* amount of curvature into the tradeoff between the two different types of investment. However, Tables 25 and 26 show that the behavior of the model is drastically different. Aggregate consumption is now procyclical. The relative volatility of investment in the investment-goods producing industry is substantially diminished (from 160.953 to 4.778), but is still larger than that of aggregate output. There is also a dramatic decline in the relative volatility of investment in the consumption-goods producing industry (from 48.531 to 2.990). This decline is further reflected in declines in the relative volatilities of the capital stocks in the two sectors. Employment in the investment-goods producing industry is less volatile, while unfortunately employment in the consumption-goods producing industry moves very little (see footnote 11 above). Additionally, with the exception of the capital stock variables, all the aggregates are now procyclical, including productivity and investment in the second industry. The capital stock, both in the aggregate and in the two sectors, essentially exhibits acyclic behavior, which is similar to what we observe in the data. In short, when $\rho = -1.2$, the behavior of this model is much more similar to the behavior of the industry-aggregates of variables illustrated in Tables 1 through 21.

Table 26 also illustrates how the cross-industry behavior of labor, capital, and labor productivity is much better behaved. The correlation of investment in the two sectors is 0.992, which is perhaps too high - the correlation in the data is 0.55.[19] Nevertheless, this is an improvement over the near perfect negative correlation (-0.969) of Table 12. We might note that Hornstein and Praschnik's sectoral model, which relies on intermediate goods to generate co-movement, is unable to generate a positive correlation between investment in the two sectors (see their Table 4). Another appealing feature of this model is the correlation of aggregate labor productivity and employment, which in this case is -0.091. One realization for these two variables is shown in Figure 3. Most real business cycle models will have this correlation being something like 0.99, whereas in the data this correlation is closer to zero. Benhabib, Rogerson and Wright (1991) stress how the introduction of home production, and with shocks to both home and domestic production, can help to reduce this correlation. Christiano and Eichenbaum (1992) employ shocks to government spending to help resolve this puzzle. The present model would indicate that a simple two-sector framework is capable of explaining this lack of perfect correlation seen in the data.[20] One benefit of this approach is that there is no need to resort to unmeasurable shocks to home production when some data or information exists on the behavior of cross-industry movements in labor and capital which can be used to discipline the behavior of the model.

Figure 4 illustrates the behavior of this model in response to a one standard deviation shock to ϵ_2, and is to be compared with Figure 2. Aggregate consumption, investment, and output, measured in consumption units all appear to move together. In fact all of the variables in these figures move in a similar manner, and hence are generally procyclical. Investment in both types of capital increases similarly, as does the size of the capital stock. Agents increase n_2 immediately, because of the increased marginal productivity of labor. Because agents wish to "smooth" consumption, k_1 and i_1 take a long time to converge back to their steady-state levels. It is interesting that n_2 displays a "cycle" in the sense that it begins below the steady-state level, and rises above before converging back to this value. The model with $\rho = -1.20$ also produces a correlation of the real rates of return of capital across industries of 0.747. This should be contrasted with the model with $\rho = -1$, where these rates of return are perfectly correlated, or with most other models of this sort which are totally reticent on this issue.

There are some other dimensions along which the model mimics the behavior of the data. For example, employment in the investment-goods industry is more strongly procyclical than is employment in the consumption-goods industry. Labor productivity in the investment-goods industry is much more procyclical than that for the consumption-goods industry. Additionally, the correlation between the level of investment and the price of a unit of capital, measured in units of the consumption good, is negative for the consumption-goods industry, but unfortunately not for the investment-goods industry. The correlation between the rates of return to specific capital goods is not as close to that of the data as one might have hoped, but it is less than one. The correlations between aggregate output and the real return to capital in the consumption goods and investment goods industries are 0.036 and 0.368 respectively. In the data these correlations are -0.32 and -0.27.

Endogenous ϕ

Arguably a more appropriate characterization of the intratemporal adjustment costs would let ϕ be endogenous, and, specifically, depend on the amount of investment that takes place. For example, relative to some benchmark, if $i_{1,t}$ were to rise, and $i_{2,t}$ were to fall, then this specialization might mean that it should be cheaper (more expensive) to produce capital goods for the consumption goods (investment goods) industry in the subsequent period, causing ϕ decrease in period t+1, relative to its previous value. One way to model this is to endogenize ϕ_t as follows :

$$\phi_t = \hat{\phi}\left(\frac{k_{1,t}\,k_{2,t-1}}{k_{1,t-1}\,k_{2,t}}\right)^{-\eta}$$

where $\eta \geq 0$, and $\hat{\phi}$ is the steady-state value of ϕ . Using this specification we found that even for values as high as $\eta = 2.0$, the resulting behavior of the economy was not substantially different from that when ϕ was held constant.

Adjustment costs for labor

A natural question to ask is whether the addition of adjustment costs for labor instead of investment goods would deliver the same qualitative and quantitative results. The simplest way to introduce such adjustment costs into this framework is to rewrite the constraint on the allocation of time as follows:

$$l_t + \zeta(\psi n_{1,t}^{-\omega} + (1-\psi)n_{2,t}^{-\omega})^{-\frac{1}{\omega}} \leq T$$

where l_t denotes consumption of leisure at date t, $\omega \leq -1$, $\zeta > 0$ and $1 \geq \psi \geq 0$. This specification of the time allocation constraint captures the idea that it is costly to re-allocate labor from one sector to the other. The parameter ψ is chosen to equate real wages across the two sectors in the non-stochastic steady state. More generally, with $\omega < -1$ real wages will not be the same in the two sectors.

Using this constraint to substitute for leisure (l_t) in the point-in-time utility function we obtain:

$$U(c_t, T - n_{1,t} - n_{2,t}) = \log(c_t) + (T - \zeta(\psi n_{1,t}^{-\omega} + (1-\psi)n_{2,t}^{-\omega})^{-\frac{1}{\omega}})$$

Obviously, with $\zeta = 2$, $\omega = -1$ and $\psi = 0.5$, this reduces to the specification of preferences in equation (6) above.

Just as was the case with investment, it would appear that there are no good measurements of the parameter ω that summarizes the difficulty in reallocating labor between the two sectors. We therefore decided to simply experiment with some different values of this parameter to see how much of a difference it makes to the behavior of our model. Table 27 summarizes the contemporaneous correlations of the various aggregates of interest when we set $\omega = -1.2$.[21] This corresponds in some loose sense to the degree of immobility assumed for new investment goods. The inclusion of adjustment costs for labor does not appear to alter the behavior of the model along many dimensions. However, along some dimensions there are significant differences. First, note that the correlation between consumption and aggregate investment is about twice as big in the model with labor adjustment costs (0.218) than in the model without these costs (0.100). Secondly, labor productivity in the investment goods sector is a lot more highly correlated with aggregate output (0.893) in the extended model than it is in the model with adjustment costs for new capital only (0.620). The correlation between the labor input in each sector is raised dramatically with the inclusion of these costs (from 0.149 to 0.996). The correlation between the aggregate labor input and aggregate labor productivity rises some (from -0.091 to 0.065) but remains close to zero. Finally, the correlation between labor productivity in each sector declines from -0.148 to -0.024.

Table 28 presents a comparison of the correlation between various leads and lags of productivity and output. Labor productivity is calculated for each sector as well as for the aggregate. Note that in neither the model with adjustment costs for new capital goods nor in the model with both types of adjustment costs is there much of a tendency for any of the productivity measures to systematically lead or lag the cycle (in the sense of having a peak correlation with aggregate output at something other than the zero lag). It is noteworthy that the addition of adjustment costs for labor raises the correlation between aggregate productivity and output at almost all leads and lags. This reflects the fact that labor productivity in sector 2 becomes more of a leading indicator, in the sense of raising the correlation between productivity in this sector and output at most lags, while lowering it at most leads. Thus imposing intratemporal adjustment costs for both capital and labor improves the behavior of aggregate and industry-specific measures of labor productivity.

IV FINAL REMARKS

Our goal in this paper has been to investigate the dimensions along which a simple real business cycle model can be extended to account for the sectoral movements in output, employment, and capital observed in the data. We showed that there is a natural reason for some inputs or outputs to tend to move in a countercyclical (and thus counterfactual) manner within a basic multisectoral model. We then showed that by introducing *intratemporal adjustment costs* for new capital goods (in conjunction with an assumption of complete immobility of existing capital goods) the behavior of the model conforms more closely with what is seen in the data.

Despite the simplicity of the model, it generates a rich array of predictions about what should be expected in the data. For example, it was possible to see how the cross-industry returns to capital behaved. The model also produces variables such as cross-industry employment, capital, labor productivity, and the behavior of these variables can also be compared with the data.

The model was shown to be consistent with the following observations from the postwar U.S. data:

- Investment, employment, and output from all sectors is procyclical.

- The variability of employment in investment goods type industries is greater than the variability of employment in consumption goods type industries.

- The capital stock in consumption and investment goods industries is acyclic.

- There is a lower correlation between aggregate labor productivity and employment than one might find in many real business cycle models.

-There is a positive correlation between investment in different sectors.

-Labor productivity in investment-goods producing industries is more highly correlated with aggregate output than is labor productivity in consumption-goods producing industries.

The model developed here can also be used to explore differences in rates of return across sectors. It is straightforward to show that in the context of this model, real rates of return to capital in different industries are less than perfectly correlated. Further results along these lines are presented in Huffman and Wynne (1995b).

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Footnotes

1. For a good review of the current state of this literature see the recent volume by Cooley (1995).

2. Burns and Mitchell state the following. "Business cycles are a type of fluctuation found in the aggregate economic activity of nations that organize their work mainly in business enterprises: a cycle consists of expansions occurring at about the same time *in many economic activities*, followed by similarly general recessions, contractions, and revivals which into the expansion phase of the next cycle; the sequence of changes is recurrent but not periodic; in duration business cycles vary from more than one year to ten or twelve years; they are not divisible into shorter cycles of similar character with amplitudes approximating their own." (Italics added)

3. Lucas employs a somewhat different definition of the business cycle than do Burns and Mitchell, as consisting of fluctuations about trend.

4. The term "multi-sector" used here refers to the fact that there is more than one production technology in the market sector, and both technologies non-trivially employ both capital and labor.

5. Benhabib, Rogerson, and Wright employ "unobservable" shocks to home production which are highly correlated with the market shocks. Greenwood and Hercowitz have the same exogenous shocks to both market and home production. In contrast, the approach of the present paper employs productivity disturbances that are directly measurable.

6. This argument was made by Black (1987). See the recent attempts along this line by Greenwood, MacDonald and Zhang (1994).

7. We focus on the eight sectors which make up the nonagricultural business sector. The idiosyncratic nature of the shocks that affect the agricultural and government sectors make them of less interest to our purpose here.

8. However serious questions can be asked about how well the output of the financial sector is measured.

9. The lead-lag relationship between residential investment and business investment has been studied by Fisher (1995).

10. Hansen (1985) uses a Cobb-Douglas version of this technology, which corresponds to having $\upsilon = 0$. However, in this context with a logarithmic utility function and a Cobb-Douglas technology, the level of employment in the consumption-goods industry is constant. Therefore, values of υ close to zero were employed in this paper since Hansen's model is a useful benchmark.

11. This picture is not totally informative since as $k_{2,t}$ or $n_{2,t}$ change, the horizontal and vertical intercepts will change as well.

12. Consequently, the decentralization of the optimal allocations is a straightforward exercise that can be conducted in the usual manner, as illustrated in Prescott and Mehra (1980).

13. Examples of such adjustment costs would be those described by Sargent (1987), chapter 10.

14. Here the period of the model is taken to be a quarter, but the sectoral data on capital and output is annual. Therefore, these parameters were estimated under the hypothesis that the actual data was generated by a quarterly process which was temporally aggregated.

15. The model's behavior was derived for 100 samples of 120 periods each.

16. In fact, having investment being so volatile causes computational problems. Investment in the two sectors is so volatile, that employing the Σ matrix shown in equation (7) results in investment in these two sectors being strongly negative in many instances. Since this is severely problematic for log-linear quadratic approximations, the matrix Σ was multiplied by .001 to produce the results shown in Tables 23 and 24.

17. The exogenous disturbances of the model are not "rigged" to produce this result since the off-diagonal elements of Σ are non-negative. Making these elements sufficiently large might help the behavior of the model, but seems quite at odds with the data.

18. There is yet another reason to be disappointed in this model. Because of the volatility in investment in the two sectors, the quadratic approximation or any such approximation technique, which is useful in studying models that do not display extreme fluctuations, becomes untrustworthy as an investigative tool when such volatility is present. Models with volatile sectors must use other techniques in order to better capture the behavior of variables far away from their steady-state values.

19. On the other hand, if one takes the data very seriously, this is not surprising since Table 3 shows that industry 2 output should be *very* highly correlated with aggregate output.

20. This also supports Aiyagari's (1994) contention that this correlation would be reduced by having more than one exogenous shock in the model.

21. We also conducted experiments with labor immobility only. For all of the values considered, we found that labor immobility alone was insufficient to overturn the counterfactual predictions of the simple two-sector model.

Appendix A

The sources for the data are as follows.

Annual:

The output series for each industry are from Table x of *National Income and Product Accounts of the United States: Volume I, 1929-58* (U.S. Department of Commerce 1993b) and *National Income and Product Accounts of the United States: Volume II, 1959-88* (U.S. Department of Commerce 1993b)

The annual full time equivalent employees series for each industry is from Table 6.5B-C of *National Income and Product Accounts of the United States: Volume II, 1959-88* (U.S. Department of Commerce 1993b) and Table 6.5B of *National Income and Product Accounts of the United States: Volume I, 1929-58* (U.S. Department of Commerce 1993b)

The capital stock series for each industry are from Table A1 of *Fixed Reproducible Tangible Wealth in the United States, 1925-1989* (U.S. Department of Commerce 1993a)

The annual investment series for each industry are drawn from Table B1 of *Fixed Reproducible Tangible Wealth in the United States, 1925-1989* (U.S. Department if Commerce 1993a)

Quarterly:

The quarterly data on employment for each industry are form the Bureau of Labor Statistics' establishment survey as recorded by CITIBASE. We look at employment of production workers only.

The quarterly data on hours worked is also form CITIBASE and refers to the average weekly hours of production workers.

Appendix B

It is useful to begin by referring to the right side of equation (3) as the level of output from the durable-goods sector. Then, the price of a unit of industry-specific capital is the amount of the consumption good that an agent would be willing to pay for it. To calculate this price, begin by calculating the relative price of a unit of the durable good in units of consumption goods. The price of a unit of sector 2 output in terms of sector 1 (consumption) output (in the extended model which includes intratemporal adjustment costs for labor and capital) is given by

$$P_t = \left(\frac{1-\psi}{\psi}\right)\left(\frac{n_{1,t}}{n_{2,t}}\right)^{1+\omega}\left[\frac{(1-\alpha_1)\lambda_{1,t}^{-\nu}n_{1,t}^{-\nu-1}[\alpha_1 k_{1,t}^{-\nu} + (1-\alpha_1)(\lambda_{1,t}n_{1,t})^{-\nu}]^{-1/\nu-1}}{(1-\alpha_2)\lambda_{2,t}^{(1-\alpha_2)}(k_{2,t}/n_{2,t})^{\alpha_2}}\right] \tag{A1}$$

Absent any problems with re-allocating labor between sectors, $\omega=-1$ and $\psi=0.5$ and this expression collapses to the standard expression for the relative price of investment goods in a two sector model. The price of a unit of the sector 1 capital good, measured in units of consumption, is then simply P_t times the (the inverse of) the increase sector #1 investment made possible by a unit increase in the output of durable goods times the (inverse of) the increase in sector 1 capital stock next period facilitated by a unit increase in sector 1 investment this period. This then can be written as follows

$$P_{1,t} = P_t\left(\frac{k_{2,t}^{\alpha_2}(\lambda_{2,t}n_{2,t}^{1-\alpha_2})}{i_{1,t}}\right)^{1+\rho}\phi$$

Substituting for P_t in this expression this last expression can be written as

$$P_{1,t} = \left(\frac{1-\psi}{\psi}\right)\left(\frac{n_{1,t}}{n_{2,t}}\right)^{1+\omega}\left[\frac{(1-\alpha_1)\lambda_{1,t}^{-\nu}n_{1,t}^{-\nu-1}[\alpha_1 k_{1,t}^{-\nu} + (1-\alpha_1)(\lambda_{1,t}n_{1,t})^{-\nu}]^{-\frac{1}{\nu}-1}}{(1-\alpha_2)\lambda_{2,t}^{(1-\alpha_2)}(k_{2,t}/n_{2,t})^{\alpha_2}}\right]\left[\frac{k_{2,t}(\lambda_{2,t}n_{2,t})^{(1-\alpha_2)}}{i_{1,t}}\right]^{(1+\rho)}\phi$$

Similarly, the price of a unit of Industry #2 capital can be written as follows

$$P_{2,t} = \left(\frac{1-\psi}{\psi}\right)\left(\frac{n_{1,t}}{n_{2,t}}\right)^{1+\omega}\left[\frac{(1-\alpha_1)\lambda_{1,t}^{-\nu}n_{1,t}^{-\nu-1}[\alpha_1 k_{1,t}^{-\nu} + (1-\alpha_1)(\lambda_{1,t}n_{1,t})^{-\nu}]^{-\frac{1}{\nu}-1}}{(1-\alpha_2)\lambda_{2,t}^{(1-\alpha_2)}(k_{2,t}/n_{2,t})^{\alpha_2}}\right]\left[\frac{k_{2,t}(\lambda_{2,t}n_{2,t})^{(1-\alpha_2)}}{i_{2,t}}\right]^{(1+\rho)}\phi$$

It can easily be shown that if $\rho = \omega = -1$ and , then the ratio of these prices is constant, and hence they are perfectly correlated. It is worth noting that the price of capital in one industry is influenced by the amount of investment undertaken in the other industry. The reason for this is as follows. Consider the experiment of increasing $i_{2,t}$ while simultaneously decreasing $i_{1,t}$, and holding employment constant. This makes industry #1 capital relatively scarce, and thereby increasing its value or price, and does the opposite to capital in the second sector. By substituting equations (3) into these pricing relationships it is easy to see that the price of each type of capital good depends on the quantity of capital in both industries.

The dividend, or marginal product of a unit of industry #1 capital, measured in units of the consumption good is

$$d_{1,t} = \alpha_1\lambda_{1,t}^{-\nu}n_{1,t}^{-\nu-1}[\alpha_1 k_{1,t}^{-\nu} + (1-\alpha_1)(\lambda_{1,t}n_{1,t})^{-\nu}]^{-\frac{1}{\nu}-1}$$

while the dividend or marginal product of a unit of industry #2 capital, measured in units of the consumption good is

$$d_{2,t} = p_t\alpha_2\lambda_{2,t}^{1-\alpha_2}\left(\frac{n_{2,t}}{k_{2,t}}\right)^{1-\alpha_2}$$

Obviously, the rates of return to capital are then easily calculated from these formulas. It is shown in Huffman and Wynne (1995) that these rates of return can be written in the form of a factor model, as is frequently done in the finance literature. This provides a link between this latter literature, and that of the dynamic general equilibrium research which is frequently employed in the study of business cycles.

Table 1

Correlations of employment with GDP

Quarterly data 1964:1-1994:2

	Group 2 Investment-type industries					Group 1 Consumption-type industries			Total	Group 1 total	Group 2 total
Lag	Mining	Construction	Manufacturing	Transportation	Wholesale	Retail	FIRE	Services			
-4	0.23	0.52	0.53	0.73	0.70	0.43	0.56	0.66	0.63	0.60	0.61
-3	0.17	0.66	0.73	0.79	0.80	0.62	0.59	0.70	0.79	0.72	0.78
-2	0.07	0.77	0.86	0.77	0.83	0.77	0.58	0.69	0.89	0.80	0.89
-1	-0.02	0.83	0.91	0.66	0.78	0.86	0.54	0.64	0.92	0.82	0.91
0	-0.13	0.79	0.84	0.49	0.64	0.86	0.45	0.52	0.83	0.75	0.82
1	-0.347	0.63	0.61	0.25	0.40	0.73	0.33	0.32	0.61	0.58	0.59
2	-0.47	0.44	0.35	0.02	0.15	0.56	0.18	0.11	0.35	0.38	0.32
3	-0.55	0.248	0.11	-0.18	-0.07	0.406	0.04	-0.106	0.11	0.18	0.08
4	-0.57	0.06	-0.09	-0.32	-0.26	0.23	-0.09	-0.28	-0.10	-0.01	-0.13
Percentage Standard Deviations											
	4.44	4.35	2.63	1.51	1.32	1.27	1.19	0.89	1.59	0.97	2.30
Percentage of labor force in each sector (1994)											
	0.5	4.3	15.9	5.1	5.3	17.9	6.0	28.0	83.0	51.9	31.1

Notes to Table: Correlations are between HP filtered series with smoothing parameter set equal to 1600. Employment shares calculated using employment data for employees on nonagricultural payrolls from Table B-44 of the Economic Report of the President 1995. Negative lags denote leads of series. Note that the entry in the row labeled lag = i is the correlation between the i'th lag of the series and aggregate output. If the peak correlation between a series and aggregate output is at the i'th lag, that indicates that the series *leads* the cycle.

Table 2 Correlations of hours with GDP Quarterly data 1964:1-1994:2											
	Group 2 Investment-type industries					Group 1 Consumption-type industries			Total	Group 1	Group 2
Lag	Mining	Construction	Manufacturing	Transportation	Wholesale	Retail	FIRE	Services			
-4	0.22	0.47	0.37	0.65	0.63	0.25	0.55	0.61	0.50	0.51	0.48
-3	0.20	0.59	0.59	0.77	0.73	0.45	0.59	0.64	0.69	0.64	0.67
-2	0.12	0.68	0.78	0.79	0.80	0.65	0.60	0.64	0.83	0.75	0.82
-1	0.06	0.75	0.90	0.74	0.80	0.80	0.57	0.60	0.92	0.81	0.91
0	-0.04	0.72	0.91	0.62	0.69	0.88	0.49	0.48	0.89	0.78	0.89
1	-0.23	0.56	0.72	0.39	0.46	0.77	0.35	0.29	0.68	0.61	0.68
2	-0.395	0.39	0.48	0.14	0.21	0.63	0.19	0.08	0.43	0.41	0.42
3	-0.49	0.21	0.25	-0.09	-0.02	0.47	0.05	-0.13	0.19	0.20	0.18
4	-0.53	0.03	0.04	-0.24	-0.21	0.31	-0.07	-0.31	-0.03	0.01	-0.04
Percentage Standard Deviations											
	5.03	5.02	3.22	1.80	1.44	1.35	1.24	0.95	1.87	0.96	2.71

Notes to Table: Correlations are between HP filtered series with smoothing parameter set equal to 1600. Note that the entry in the row labeled lag = *i* is the correlation between the i'th lag of the series and aggregate output. If the peak correlation between a series and aggregate output is at the *i*'th lag, that indicates that the series *leads* the cycle.

Table 3

Correlations of sectoral output with aggregate output

Annual data 1947-1991

	Group 2 Investment-type industries					Group 1 Consumption-type industries			Total	Group 1	Group 2
Lag	Mining	Construction	Manufacturing	Transportation	Wholesale	Retail	FIRE	Services			
-2	-0.07	-0.21	-0.11	-0.09	-0.14	-0.26	0.15	-0.06	-0.15	-0.11	-0.15
-1	0.26	0.35	0.36	0.38	0.04	0.10	0.27	0.39	0.38	0.32	0.38
0	0.60	0.82	0.95	0.78	0.53	0.76	0.38	0.66	1.00	0.86	0.99
1	0.23	0.43	0.38	0.12	0.29	0.60	-0.27	0.07	.38	0.27	0.39
2	-0.07	0.04	-0.07	-0.37	-0.01	0.17	-0.66	-0.35	-0.15	-0.30	-0.10
Percentage Standard Deviations											
	4.70	4.83	5.12	2.80	3.43	3.20	1.08	1.48	2.42	1.24	3.69
Sector output as a fraction of 1992 GDP											
	1.8	4.0	18.6	9.9	6.8	9.8	17.9	17.9	86.8	45.6	41.2

Notes to Table: Correlations are between HP filtered series with smoothing parameter set equal to 100. Aggregate output defined as the sum of outputs produced in each sector measured in 1987 dollars. Data on shares taken from table B-12 of the Economic Report of the President 1995. Note that the entry in the row labeled lag = *i* is the correlation between the i'th lag of the series and aggregate output. If the peak correlation between a series and aggregate output is at the *i*'th lag, that indicates that the series *leads* the cycle.

Table 4 Correlations of total capital with aggregate output Annual data 1948-1992											
	Group 2 Investment-type industries					Group 1 Consumption-type industries			Total	Group 1	Group 2
Lag	Mining	Construction	Manufacturing	Transportation	Wholesale	Retail	FIRE	Services			
-2	-0.07	0.29	0.45	0.36	-0.05	0.16	0.18	0.18	0.43	0.18	0.38
-1	-0.11	0.45	0.39	0.35	0.31	0.17	0.28	0.34	0.50	0.29	0.39
0	-0.12	0.38	-0.03	0.01	0.54	0.27	0.31	0.30	0.21	0.32	0.03
1	-0.16	0.05	-0.41	-0.39	0.34	0.06	-0.00	-0.16	-0.33	-0.02	-0.41
2	-0.09	0.02	-0.32	-0.36	0.24	0.10	-0.21	-0.42	-0.34	-0.21	-0.33
Percentage Standard Deviations											
	4.82	4.33	1.99	1.00	3.43	1.68	1.96	1.76	1.10	1.72	1.19
Fraction of capital stock in each sector (1989)											
	4.7	1.2	21.4	24.4	4.7	6.8	23.7	9.3	96.2	39.9	56.3

Notes to Table: Note that the entry in the row labeled lag = i is the correlation between the i'th lag of the series and aggregate output. If the peak correlation between a series and aggregate output is at the i'th lag, that indicates that the series *leads* the cycle.

Table 5

Correlation of capital equipment with aggregate output

Annual data 1948-1992

	Group 2 Investment-type industries					Group 1 Consumption-type industries			Total	Group 1	Group 2
Lag	Mining	Construction	Manufacturing	Transportation	Wholesale	Retail	FIRE	Services			
-2	0.08	0.35	0.44	0.37	0.02	0.14	0.20	0.35	0.43	0.28	0.42
-1	0.02	0.48	0.38	0.46	0.37	0.32	0.24	0.43	0.54	0.37	0.49
0	-0.06	0.35	0.03	0.19	0.57	0.45	0.25	0.36	0.30	0.38	0.20
1	-0.19	-0.00	-0.32	-0.24	0.33	0.10	-0.10	-0.10	-0.21	-0.07	-0.25
2	-0.15	-0.08	-0.25	-0.16	0.21	-0.00	-0.16	-0.33	0.24	-0.23	-0.19
Percentage standard deviations											
	5.31	5.27	2.33	1.79	5.26	2.89	4.64	3.86	1.99	3.44	1.87
Fraction of capital stock (equipment) in each sector (1989)											
	3.0	1.5	26.3	22.7	5.8	6.0	18.8	12.4	96.5	37.2	59.3

Table 6

Correlations capital structures with aggregate output

Annual data 1947-1991

	Group 2 Investment-type industries					Group 1 Consumption-type industries			Total	Group 1	Group 2
Lag	Mining	Construction	Manufacturing	Transportation	Wholesale	Retail	FIRE	Services			
-2	-0.11	0.01	0.31	0.18	-0.15	0.07	0.08	-0.23	0.16	0.01	0.13
-1	-0.14	0.14	0.26	0.05	-0.01	-0.05	0.16	-0.14	0.15	0.05	0.05
0	-0.11	0.19	-0.14	-0.21	0.11	-0.04	0.19	-0.05	-0.04	0.10	-0.21
1	-0.13	0.22	-0.44	-0.40	0.11	-0.02	0.05	0.02	-0.26	0.03	-0.42
2	-0.05	0.31	-0.36	-0.34	0.09	0.12	-0.10	0.11	-0.21	-0.01	-0.30
Percentage Standard Deviations											
	4.76	3.59	2.15	0.76	3.25	2.20	2.00	2.71	1.08	2.01	1.15
Fraction of capital stock (structures) in each sector (1989)											
	6.2	0.9	17.1	25.9	3.8	7.4	27.9	6.8	95.9	42.1	53.8

Table 7

Correlations of Solow residuals with aggregate output

Annual data 1948-1992

	Group 2 Investment-type industries					Group 1 Consumption-type industries			Total	Group 1	Group 2
Lag	Mining	Construction	Manufacturing	Transportation	Wholesale	Retail	FIRE	Services			
-2	0.01	-0.28	-0.29	-0.33	-0.30	-0.22	-0.11	0.11	-0.37	-0.12	-0.37
-1	0.27	-0.28	0.13	0.05	-0.41	-0.15	-0.15	0.41	0.02	-0.06	0.04
0	0.52	0.02	0.81	0.68	0.19	0.49	0.11	0.44	0.81	0.46	0.79
1	0.38	0.38	0.59	0.34	0.29	0.55	-0.02	0.23	0.65	0.32	0.67
2	0.06	0.42	0.19	0.01	0.21	0.22	-0.27	-0.03	0.18	-0.10	0.25
Percentage Standard Deviations											
	6.69	3.30	3.14	2.06	2.84	2.44	1.58	1.05	1.41	0.96	2.24

Notes to Table: Correlations are between HP filtered series with smoothing parameter set equal to 100. Note that the entry in the row labeled lag = i is the correlation between the i'th lag of the series and aggregate output. If the peak correlation between a series and aggregate output is at the i'th lag, that indicates that the series *leads* the cycle.

Table 8 Correlation of labor productivity with aggregate output Annual data 1948-1992											
	Group 2 Investment-type industries					Group 1 Consumption-type industries			Total	Group 1	Group 2
Lag	Mining	Construction	Manufacturing	Transportation	Wholesale	Retail	FIRE	Services			
-2	-0.08	-0.20	-0.33	-0.41	-0.16	-0.15	-0.02	0.19	-0.34	0.24	-0.42
-1	0.12	-0.32	-0.11	-0.37	-0.29	-0.21	-0.33	0.43	-0.42	-0.13	-0.34
0	0.40	-0.13	0.53	0.23	0.14	0.34	-0.35	0.32	0.17	-0.03	0.30
1	0.52	0.35	0.70	0.41	0.37	0.51	-0.21	0.16	0.70	0.10	0.74
2	0.24	0.45	0.38	0.22	0.31	0.26	-0.06	-0.01	0.48	-0.02	0.52
Percentage Standard Deviations											
	8.43	3.34	2.20	1.90	3.44	2.29	1.58	1.08	0.99	0.66	1.77

Notes to Table: Correlations are between HP filtered series with smoothing parameter set equal to 100. Productivity is defined as GDP per hour. Note that the entry in the row labeled lag = *i* is the correlation between the i'th lag of the series and aggregate output. If the peak correlation between a series and aggregate output is at the *i*'th lag, that indicates that the series *leads* the cycle.

Table 9

Correlations of sectoral investment flows with aggregate output

Annual data 1947-1991

	Group 2 Investment-type industries					Group 1 Consumption-type industries			Total	Group 1	Group 2
Lag	Mining	Construction	Manufacturing	Transportation	Wholesale	Retail	FIRE	Services			
-2	0.05	-0.11	0.14	0.09	-0.43	0.06	-0.06	-0.15	0.01	-0.06	0.07
-1	0.06	0.34	0.65	0.60	-0.11	-0.04	0.10	0.19	0.56	0.10	0.63
0	0.01	0.71	0.53	0.65	0.45	0.24	0.47	0.69	0.78	0.54	0.67
1	-0.24	0.25	-0.04	-0.06	0.24	-0.07	0.18	0.26	-0.01	0.16	-0.12
2	-0.20	-0.06	-0.33	-0.21	0.06	-0.05	-0.01	-0.35	-0.33	-0.11	-0.34
Percentage Standard Deviations											
	13.00	13.45	11.93	7.38	13.14	10.09	11.04	7.82	6.47	8.59	7.24
Sectoral investment as a fraction of total private fixed nonresidential investment (1989)											
	3.7	1.3	21.7	17.3	5.8	8.3	26.5	12.5	97.1	47.3	49.8

Notes to Table: Correlations are between HP filtered series with smoothing parameter set equal to 100. Investment shares calculated as investment (in 1987 dollars) in each sector as a fraction of investment in all sectors in 1989. Note that the entry in the row labeled lag $= i$ is the correlation between the i'th lag of the series and aggregate output. If the peak correlation between a series and aggregate output is at the i'th lag, that indicates that the series *leads* the cycle.

Table 10 Correlation of implicit deflator for total investment (in consumption units) with aggregate output Annual data 1948-1992											
	Group 2 Investment-type industries					Group 1 Consumption-type industries			Total	Group 1	Group 2
Lag	Mining	Construction	Manufacturing	Transportation	Wholesale	Retail	FIRE	Services			
-2	0.03	0.06	0.08	-0.25	0.02	-0.14	0.02	0.04	0.00	0.00	-0.03
-1	-0.12	-0.36	-0.04	-0.44	-0.07	0.12	0.23	-0.06	-0.25	0.14	-0.30
0	-0.36	-0.57	-0.35	-0.38	-0.14	0.03	0.23	-0.11	-0.42	0.09	-0.51
1	-0.45	-0.21	-0.23	-0.11	-0.15	-0.14	-0.14	-0.11	-0.35	-0.18	-0.39
2	-0.23	0.19	0.00	-0.09	0.17	-0.19	-0.18	0.09	-0.10	-0.12	-0.13
Percentage Standard Deviations											
	5.41	3.52	2.07	2.23	2.44	1.84	1.92	2.42	1.93	1.71	2.34

Notes to Table: Correlations are between HP filtered series with smoothing parameter set equal to 100. Price series defined as the ratio of the implicit deflator for investment in each sector to the implicit deflator for consumption. Note that the entry in the row labeled lag = i is the correlation between the i'th lag of the series and aggregate output. If the peak correlation between a series and aggregate output is at the i'th lag, that indicates that the series *leads* the cycle.

Table 11

Correlations of sectoral structures investment flows with aggregate output

Annual data 1947-1991

	Group 2 Investment-type industries					Group 1 Consumption-type industries			Total	Group 1	Group 2
Lag	Mining	Construction	Manufacturing	Transportation	Wholesale	Retail	FIRE	Services			
-2	0.03	-0.20	0.09	0.24	-0.13	0.24	-0.09	-0.18	0.08	-0.03	0.16
-1	-0.01	0.00	0.56	0.48	-0.06	-0.01	0.04	-0.17	0.41	0.00	0.53
0	-0.05	0.12	0.38	0.34	0.05	-0.07	0.28	-0.15	0.38	0.15	0.34
1	-0.24	-0.03	-0.18	-0.14	-0.01	-0.28	0.14	-0.31	-0.21	-0.05	-0.29
2	-0.16	0.02	-0.34	-0.07	0.14	0.03	0.03	-0.24	-0.24	-0.02	-0.28
Percentage Standard Deviations											
	13.76	17.51	16.86	7.52	24.94	20.10	12.91	12.23	7.02	11.65	7.63
Sectoral investment as a fraction of total private fixed nonresidential investment (1989)											
	7.2	0.6	19.9	19.2	3.4	9.3	31.3	7.6	98.5	26.8	71.7

Notes to Table: Correlations are between HP filtered series with smoothing parameter set equal to 100. Investment shares calculated as investment (in 1987 dollars) in each sector as a fraction of investment in all sectors in 1989.

Table 12

Correlations of different categories of investment with GDP

Quarterly data 1947:1-1994:2

Lag	Gross Investment	Fixed Investment	Investment in structures	Producers durable equipment investment	Residential investment
-4	-0.168	-0.041	0.416	0.242	-0.347
-3	0.058	0.165	0.521	0.468	-0.209
-2	0.322	0.393	0.579	0.664	-0.004
-1	0.585	0.607	0.559	0.799	0.243
0	0.782	0.737	0.458	0.798	0.476
1	0.712	0.691	0.243	0.611	0.595
2	0.569	0.553	0.028	0.371	0.607
3	0.380	0.378	-0.159	0.141	0.547
4	0.194	0.216	-0.284	-0.030	0.452
Percentage Standard Deviations					
	8.25	5.55	4.75	6.16	10.92

Notes to Table: Correlations are between HP filtered series with smoothing parameter set equal to 1600.

Table 13

Correlation of implicit deflator for total investment with aggregate output

Annual data 1948-1992

	Group 2 Investment-type industries					Group 1 Consumption-type industries			Total	Group 1	Group 2
Lag	Mining	Construction	Manufacturing	Transportation	Wholesale	Retail	FIRE	Services			
-2	0.03	0.06	0.06	-0.16	0.03	-0.07	0.03	0.04	0.01	0.02	0.00
-1	-0.13	-0.35	-0.10	-0.39	-0.12	-0.01	0.06	-0.12	-0.22	-0.01	-0.25
0	-0.38	-0.61	-0.42	-0.48	-0.29	-0.20	-0.08	-0.27	-0.44	-0.18	-0.50
1	-0.49	-0.38	-0.42	-0.36	-0.37	-0.39	-0.42	-0.35	-0.48	-0.43	-0.49
2	-0.22	0.09	-0.09	-0.16	0.03	-0.15	-0.22	-0.03	-0.15	-0.17	-0.16
Percentage Standard Deviations											
	6.86	4.36	3.33	3.18	3.52	3.08	2.92	3.44	3.34	2.89	3.75

Table 14

Correlation of implicit deflator for equipment investment with aggregate output

Annual data 1948-1992

	Group 2 Investment-type industries					Group 1 Consumption-type industries			Total	Group 1	Group 2
Lag	Mining	Construction	Manufacturing	Transportation	Wholesale	Retail	FIRE	Services			
-2	0.05	0.05	0.07	-0.18	0.09	0.05	-0.08	-0.05	-0.03	-0.03	-0.04
-1	-0.32	-0.36	-0.15	-0.49	-0.20	-0.15	-0.12	-0.28	-0.35	-0.20	-0.34
0	-0.52	-0.60	-0.46	-0.54	-0.49	-0.45	-0.29	-0.47	-0.52	-0.41	-0.54
1	-0.30	-0.34	-0.37	-0.33	-0.41	-0.45	-0.15	-0.33	-0.36	-0.34	-0.39
2	-0.03	0.12	-0.03	0.02	0.09	0.01	0.06	0.08	0.03	0.06	0.00
Percentage Standard Deviations											
	4.79	4.57	3.92	3.29	4.21	3.58	4.16	4.60	3.61	3.90	3.66

Table 15

Correlation of implicit deflator for structures investment with aggregate output

Annual data 1948-1992

	Group 2 Investment-type industries					Group 1 Consumption-type industries			Total	Group 1	Group 2
Lag	Mining	Construction	Manufacturing	Transportation	Wholesale	Retail	FIRE	Services			
-2	0.02	0.25	0.03	-0.07	0.03	0.03	0.04	0.04	0.06	0.04	0.03
-1	-0.07	-0.06	0.15	-0.18	0.15	0.15	0.15	0.16	-0.02	0.15	-0.11
0	-0.33	-0.13	-0.12	-0.36	-0.12	-0.12	-0.13	-0.12	-0.31	-0.12	-0.37
1	-0.52	-0.25	-0.53	-0.37	-0.52	-0.52	-0.52	-0.52	-0.56	-0.52	-0.55
2	-0.27	-0.03	-0.30	-0.31	-0.29	-0.30	-0.29	-0.31	-0.36	-0.30	-0.35
Percentage Standard Deviations											
	8.22	6.70	3.06	3.57	3.07	3.06	3.06	3.11	3.84	3.07	4.52

Table 16

Correlation of implicit deflator for total investment (in consumption units) with aggregate output

Annual data 1948-1992

	Group 2 Investment-type industries					Group 1 Consumption-type industries			Total	Group 1	Group 2
Lag	Mining	Construction	Manufacturing	Transportation	Wholesale	Retail	FIRE	Services			
-2	0.03	0.06	0.08	-0.25	0.02	-0.14	0.02	0.04	0.00	0.00	-0.03
-1	-0.12	-0.36	-0.04	-0.44	-0.07	0.12	0.23	-0.06	-0.25	0.14	-0.30
0	-0.36	-0.57	-0.35	-0.38	-0.14	0.03	0.23	-0.11	-0.42	0.09	-0.51
1	-0.45	-0.21	-0.23	-0.11	-0.15	-0.14	-0.14	-0.11	-0.35	-0.18	-0.39
2	-0.23	0.19	0.00	-0.09	0.17	-0.19	-0.18	0.09	-0.10	-0.12	-0.13
Percentage Standard Deviations											
	5.41	3.52	2.07	2.23	2.44	1.84	1.92	2.42	1.93	1.71	2.34

Notes to Table: Correlations are between HP filtered series with smoothing parameter set equal to 100. Price series defined as the ratio of the implicit deflator for investment in each sector to the implicit deflator for consumption.

Table 17

Correlation of equipment investment prices (in consumption units) with aggregate output

Annual data 1948-1992

	Group 2 Investment-type industries					Group 1 Consumption-type industries			Total	Group 1	Group 2
Lag	Mining	Construction	Manufacturing	Transportation	Wholesale	Retail	FIRE	Services			
-2	0.05	0.05	0.08	-0.27	0.11	0.06	-0.12	-0.08	-0.06	-0.06	-0.08
-1	-0.35	-0.37	-0.12	-0.57	-0.19	-0.13	-0.07	-0.27	-0.41	-0.18	-0.39
0	-0.51	-0.56	-0.43	-0.47	-0.45	-0.40	-0.16	-0.39	-0.49	-0.33	-0.53
1	-0.15	-0.17	-0.20	-0.07	-0.25	-0.29	0.09	-0.16	-0.15	-0.14	-0.20
2	0.04	0.22	0.06	0.15	0.22	0.14	0.17	0.18	0.16	0.18	0.12
Percentage Standard Deviations											
	3.60	3.74	2.68	2.37	3.10	2.37	3.28	3.78	2.45	2.87	2.50

Notes to Table: Correlations are between HP filtered series with smoothing parameter set equal to 100. Price series defined as the ratio of the implicit deflator for equipment investment in each sector to the implicit deflator for consumption.

Table 18

Correlation of structures investment prices (in consumption units) with aggregate output

Annual data 1948-1992

	Group 2 Investment-type industries					Group 1 Consumption-type industries			Total	Group 1	Group 2
Lag	Mining	Construction	Manufacturing	Transportation	Wholesale	Retail	FIRE	Services			
-2	0.02	0.26	0.01	-0.11	0.02	0.02	0.03	0.04	0.07	0.03	0.03
-1	-0.05	-0.03	0.31	-0.14	0.31	0.31	0.32	0.33	0.06	0.32	-0.07
0	-0.30	-0.04	0.13	-0.23	0.13	0.13	0.12	0.13	-0.21	0.13	-0.32
1	-0.49	-0.13	-0.30	-0.15	-0.30	-0.29	-0.30	-0.31	-0.49	-0.30	-0.49
2	-0.28	0.02	-0.27	-0.30	-0.26	-0.27	-0.26	0.30	-0.42	-0.27	-0.41
Percentage Standard Deviations											
	6.85	6.17	2.26	2.75	2.27	2.27	2.27	2.29	2.56	2.27	3.17

Notes to Table: Correlations are between HP filtered series with smoothing parameter set equal to 100. Price series defined as the ratio of the implicit deflator for structures investment in each sector to the implicit deflator for consumption.

Table 19

Correlations of real wages with aggregate output

Quarterly data 1964:1-1994:2

	Group 2 Investment-type industries					Group 1 Consumption-type industries			Total	Group 1	Group 2
Lag	Mining	Construction	Manufacturing	Transportation	Wholesale	Retail	FIRE	Services			
-4	0.02	-0.04	-0.17	-0.15	-0.04	-0.22	-0.11	-0.22	-0.07	-0.25	-0.14
-3	0.06	-0.03	0.05	0.03	0.06	-0.10	-0.08	-0.16	0.13	-0.18	0.05
-2	0.11	-0.03	0.30	0.23	0.25	0.11	0.03	-0.05	0.36	-0.02	0.28
-1	0.21	0.01	0.56	0.43	0.42	0.31	0.14	0.06	0.58	0.14	0.53
0	0.27	0.03	0.78	0.60	0.53	0.53	0.24	0.17	0.74	0.32	0.72
1	0.23	0.01	0.79	0.65	0.55	0.60	0.30	0.27	0.73	0.42	0.73
2	0.14	0.06	0.70	0.61	0.51	0.60	0.34	0.32	0.64	0.46	0.67
3	0.05	0.07	0.59	0.52	0.46	0.54	0.35	0.33	0.52	0.45	0.57
4	-0.02	0.04	0.47	0.44	0.38	0.46	0.30	0.32	0.38	0.41	0.44
Percentage Standard Deviations											
	1.52	2.21	1.32	1.34	0.75	0.89	0.84	0.79	0.94	0.66	1.06

Notes to Table: Correlations are between HP filtered series with smoothing parameter set equal to 1600. Aggregate wages for group 1, group 2 and total are weighted averages of wages in each sector using employment shares as weights. Real wages are measured as the nominal average hourly wage multiplied by the number of hours worked per quarter, divided by the number of employees and deflated by the GDP deflator.

Table 20 Correlations of nominal rates of return with aggregate output Quarterly data 1949:1-1994:2											
	Group 2 Investment-type industries					Group 1 Consumption-type industries			Total	Group 1	Group 2
Lag	Mining	Construction	Manufacturing	Transportation	Wholesale	Retail	FIRE	Services			
-4	0.01	0.10	-0.02	-0.02	0.04	0.06	0.03	0.09	-0.01	0.05	-0.01
-3	0.00	0.03	-0.14	-0.11	-0.09	-0.09	-0.05	-0.04	-0.12	-0.07	-0.12
-2	-0.04	-0.03	-0.22	-0.17	-0.15	-0.20	-0.12	-0.14	-0.20	-0.17	-0.20
-1	-0.09	-0.12	-0.27	-0.21	-0.20	-0.29	-0.20	-0.21	-0.25	-0.25	-0.25
0	-0.05	-0.10	-0.25	-0.30	-0.21	-0.35	-0.26	-0.25	-0.27	-0.31	-0.26
1	0.02	-0.03	-0.12	-0.20	-0.14	-0.26	-0.16	-0.14	-0.14	-0.21	-0.13
2	0.15	0.09	0.06	-0.03	-0.02	-0.11	0.01	-0.01	0.04	-0.04	0.05
3	0.22	0.14	0.14	0.04	0.03	-0.06	0.13	0.05	0.12	0.06	0.13
4	0.25	0.17	0.18	0.09	0.07	0.01	0.16	0.11	0.16	0.11	0.17
Percentage Standard Deviations											
	10.74	14.73	8.31	6.5	12.0	10.7	8.96	13.07	7.79	9.25	7.59

Notes to Table: Correlations are between HP filtered GDP at date t (with smoothing parameter set equal to 1600) and unfiltered returns. Data on returns are for firms listed on the NYSE.

Table 21

Correlations of real rates of return with aggregate output

Quarterly data 1949:1-1994:2

	Group 2 Investment-type industries					Group 1 Consumption-type industries			Total	Group 1	Group 2
Lag	Mining	Construction	Manufacturing	Transportation	Wholesale	Retail	FIRE	Services			
-4	0.00	0.10	-0.03	-0.04	0.03	0.05	0.02	0.08	-0.02	0.04	-0.03
-3	-0.01	0.03	-0.15	-0.12	-0.09	-0.10	-0.06	-0.05	-0.13	-0.08	-0.13
-2	-0.05	-0.04	-0.23	-0.18	-0.15	-0.21	-0.13	-0.15	-0.21	-0.18	-0.21
-1	-0.10	-0.13	-0.28	-0.23	-0.21	-0.30	-0.21	-0.22	-0.27	-0.26	-0.27
0	-0.06	-0.11	-0.26	-0.31	-0.22	-0.36	-0.27	-0.25	-0.28	-0.32	-0.27
1	0.01	-0.04	-0.13	-0.22	-0.15	-0.27	-0.17	-0.15	-0.16	-0.22	-0.15
2	0.14	0.09	0.05	-0.04	-0.02	-0.12	0.00	-0.02	0.03	-0.04	0.04
3	0.22	0.14	0.14	0.04	0.03	-0.06	0.12	0.05	0.12	0.06	0.13
4	0.25	0.17	0.18	0.09	0.07	0.01	0.16	0.11	0.17	0.11	0.17
Percentage Standard Deviations											
	10.78	14.73	8.39	6.59	12.00	10.82	9.04	13.10	7.87	9.34	7.67

Notes to Table: Correlations are between HP filtered GDP at date t (with smoothing parameter set equal to 1600) and unfiltered returns. Real return calculated by subtracting the rate of inflation of the implicit deflator for personal consumption expenditures from the nominal return. Data on returns are for firms listed on the NYSE.

Table 22

Cyclical behavior of aggregate output

Fixed weight measures, 1947:1-1994:4

		Correlation of real GDP with								
	Volatility	x(t-4)	x(t-3)	x(t-2)	x(t-1)	x(t)	x(t+1)	x(t+2)	x(t+3)	x(t+4)
Real Gross Domestic Product	1.783	0.163	0.391	0.640	0.857	1.000	0.857	0.640	0.391	0.163
Personal Consumption expenditures	1.182	0.325	0.478	0.619	0.725	0.734	0.567	0.344	0.115	-0.064
Nondurables and services	0.822	0.215	0.413	0.604	0.749	0.778	0.657	0.469	0.285	0.127
Nondurables	1.163	0.202	0.357	0.529	0.669	0.718	0.635	0.463	0.276	0.124
Services	0.715	0.187	0.400	0.577	0.694	0.692	0.543	0.371	0.228	0.089
Durables	5.439	0.369	0.423	0.462	0.495	0.475	0.292	0.080	-0.148	-0.311
Investment Expenditures	8.238	0.200	0.386	0.575	0.717	0.784	0.589	0.328	0.066	-0.160
Fixed Investment	5.544	0.227	0.389	0.561	0.695	0.741	0.611	0.398	0.173	-0.034
Nonresidential	5.166	-0.100	0.068	0.294	0.538	0.746	0.781	0.692	0.533	0.332
Structures	4.772	-0.276	-0.153	0.034	0.251	0.465	0.564	0.583	0.526	0.420
Equipment	6.153	-0.017	0.155	0.379	0.615	0.801	0.802	0.668	0.474	0.247
Residential	10.851	0.457	0.553	0.611	0.597	0.475	0.243	-0.004	-0.207	-0.346
Government Purchases	3.833	-0.075	-0.008	0.091	0.213	0.344	0.419	0.464	0.470	0.442
Labor Income	1.832	0.004	0.207	0.443	0.693	0.885	0.887	0.779	0.603	0.392
Capital Income	3.527	0.251	0.416	0.574	0.691	0.726	0.502	0.219	-0.027	-0.216
Proprietors' Income & Misc.	2.807	0.203	0.332	0.497	0.589	0.658	0.500	0.362	0.202	0.095

Table 23

Basic model with $\rho = -1.0$

Variable	Standard deviation relative to output	Correlation with output
c	0.491	-0.739
i	4.858	0.982
i_1	48.531	0.279
i_2	160.953	-0.155
n	1.416	0.978
n_1	0.010	0.913
n_2	4.745	0.978
π	0.484	-0.796
π_1	0.498	-0.747
π_2	0.226	0.569
k	0.283	-0.015
k_1	1.068	-0.904
k_2	3.957	0.952

Table 24

Contemporaneous correlations of key aggregates

Model with $\rho = -1.0$

	y	c	i	i_1	i_2	n	n_1	n_2	k	k_1	k_2	π	π_1	π_2
y														
c	-0.739													
i	0.982	-0.852												
i_1	0.279	-0.381	0.323											
i_2	-0.155	0.276	-0.198	-0.983										
n	0.978	-0.860	0.999	0.328	-0.203									
n_1	0.913	-0.718	0.908	0.353	-0.241	0.916								
n_2	0.978	-0.860	0.999	0.328	-0.203	1.000	0.915							
k	-0.015	0.297	-0.095	0.286	-0.308	-0.123	-0.303	-0.122						
k_1	-0.904	0.902	0.953	-0.394	0.276	-0.961	-0.947	-0.961	0.324					
k_2	0.952	-0.849	0.976	0.516	-0.399	0.974	0.894	0.974	0.008	-0.943				
π	-0.796	0.989	-0.897	-0.383	0.274	-0.904	-0.793	-0.904	0.328	0.944	-0.882			
π_1	-0.747	1.000	-0.858	-0.382	0.277	-0.866	-0.727	-0.866	0.299	0.908	-0.855	0.990		
π_2	0.562	-0.271	0.516	0.055	0.016	0.481	0.319	0.481	0.516	-0.322	0.521	-0.231	-0.273	

Table 25 Model with $\rho = -1.2$		
	Standard deviation relative to output	Correlation with output
c	0.492	0.445
i	3.393	0.931
i_1	2.990	0.932
i_2	4.778	0.924
n	0.966	0.931
n_1	0.008	0.464
n_2	3.270	0.927
π	0.365	0.274
π_1	0.484	0.448
π_2	0.205	0.620
k	0.199	-0.046
k_1	0.172	-0.083
k_2	0.310	0.034

Table 26

Contemporaneous correlations of key aggregates

Model with $\rho = -1.2$

	y	c	i	i_1	i_2	n	n_1	n_2	k	k_1	k_2	π	π_1	π_2
y														
c	0.445													
i	0.931	0.100												
i_1	0.932	0.104	0.999											
i_2	0.924	0.090	0.996	0.992										
n	0.931	0.100	0.999	0.997	0.999									
n_1	0.464	0.939	0.141	0.132	0.158	0.155								
n_2	0.927	0.094	0.999	0.996	0.999	0.999	0.149							
k	-0.046	0.108	-0.095	-0.057	-0.177	-0.135	-0.229	-0.134						
k_1	-0.083	0.104	-0.135	-0.096	-0.214	-0.174	-0.234	-0.173	0.998					
k_2	0.034	0.114	0.008	0.031	-0.091	-0.048	-0.215	-0.047	0.988	0.974				
π	0.274	0.972	-0.087	-0.078	-0.106	-0.091	0.867	-0.099	0.228	0.231	0.218			
π_1	0.448	1.000	0.099	0.104	0.088	0.099	0.937	0.093	0.113	0.109	0.119	0.973		
π_2	0.620	0.145	0.616	0.642	0.556	0.594	-0.040	0.578	0.562	0.533	0.616	0.132	0.148	

Table 27

Contemporaneous correlations of key aggregates

Model with $\rho = -1.2$ and $\omega = -1.2$

	y	c	i	i_1	i_2	n	n_1	n_2	k	k_1	k_2	π	π_1	π_2
y														
c	0.587													
i	0.915	0.218												
i_1	0.916	0.221	0.999											
i_2	0.909	0.209	0.997	0.993										
n	0.915	0.219	0.999	0.997	0.999									
n_1	0.932	0.261	0.997	0.994	0.997	0.998								
n_2	0.911	0.213	0.996	0.996	0.999	0.999	0.996							
k	-0.043	0.095	-0.099	-0.061	-0.177	-0.140	-0.147	-0.138						
k_1	-0.078	0.087	-0.137	-0.098	-0.214	-0.177	-0.184	-0.176	0.998					
k_2	0.032	0.110	-0.015	0.023	-0.095	-0.056	-0.064	-0.055	0.989	0.977				
π	0.457	0.981	0.068	0.076	0.052	0.065	0.111	0.057	0.202	0.199	0.205			
π_1	0.347	0.962	-0.052	-0.047	-0.061	-0.051	-0.008	-0.056	0.138	0.141	0.131	0.065		
π_2	0.893	0.233	0.960	0.968	0.938	0.950	0.954	0.944	0.116	0.078	0.197	0.122	-0.024	

Table 28

Correlation of productivity with aggregate output

Model with $\rho = -1.2$ and $\omega = -1.0$									
Lag	4	3	2	1	0	-1	-2	-3	-4
π	-0.154	-0.127	-0.061	0.058	0.237	0.180	0.140	0.121	0.106
π_1	-0.097	-0.046	0.048	0.202	0.422	0.269	0.157	0.092	0.047
π_2	-0.275	-0.163	0.013	0.270	0.623	0.578	0.513	0.436	0.359
Model with $\rho = -1.2$ and $\omega = -1.2$									
Lag	4	3	2	1	0	-1	-2	-3	-4
π	-0.141	-0.074	0.041	0.212	0.457	0.317	0.210	0.131	0.079
π_1	-0.113	-0.067	0.020	0.153	0.347	0.225	0.134	0.072	0.035
π_2	-0.060	-0.088	0.291	0.554	0.893	0.634	0.423	0.247	0.108

Figure 1

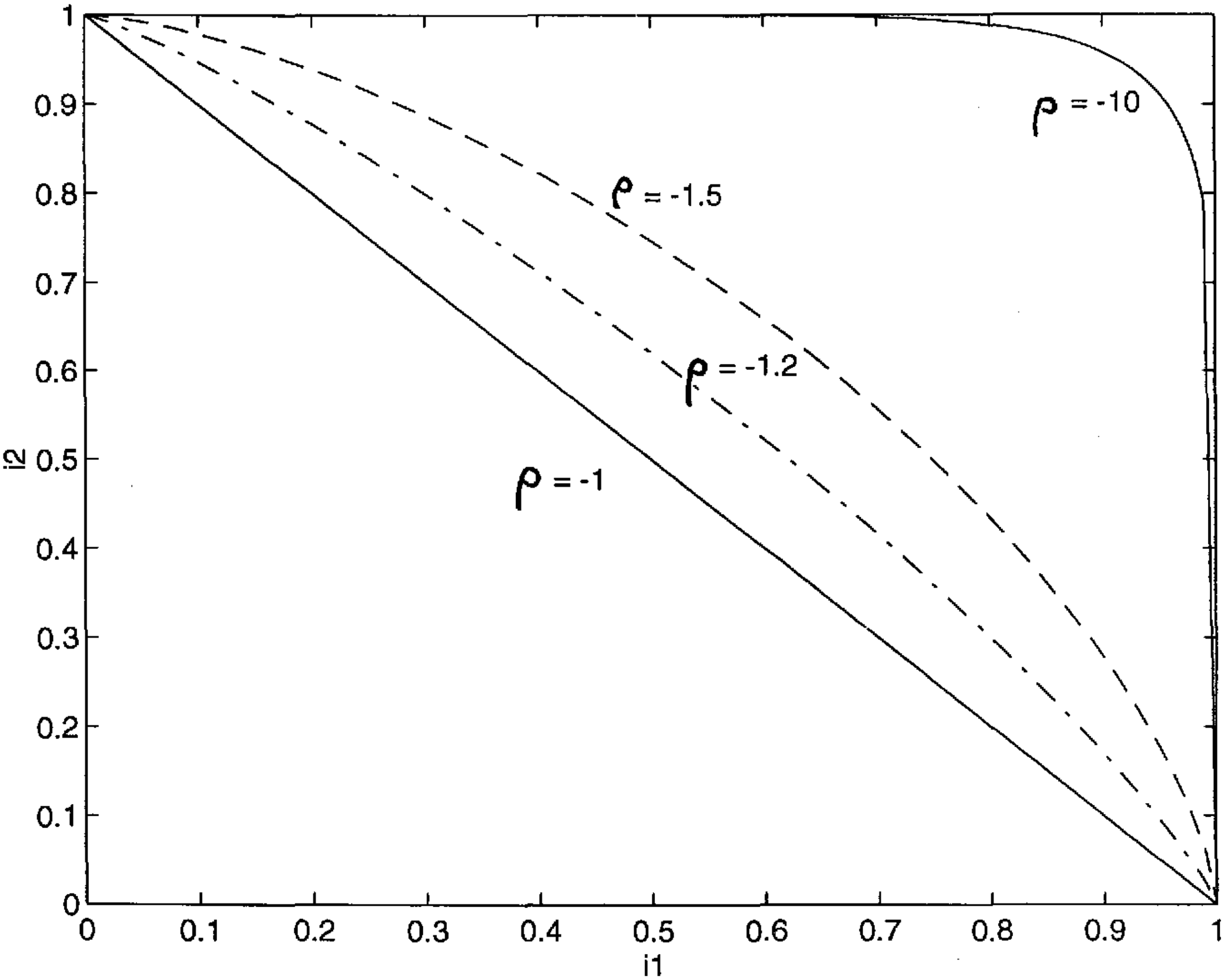
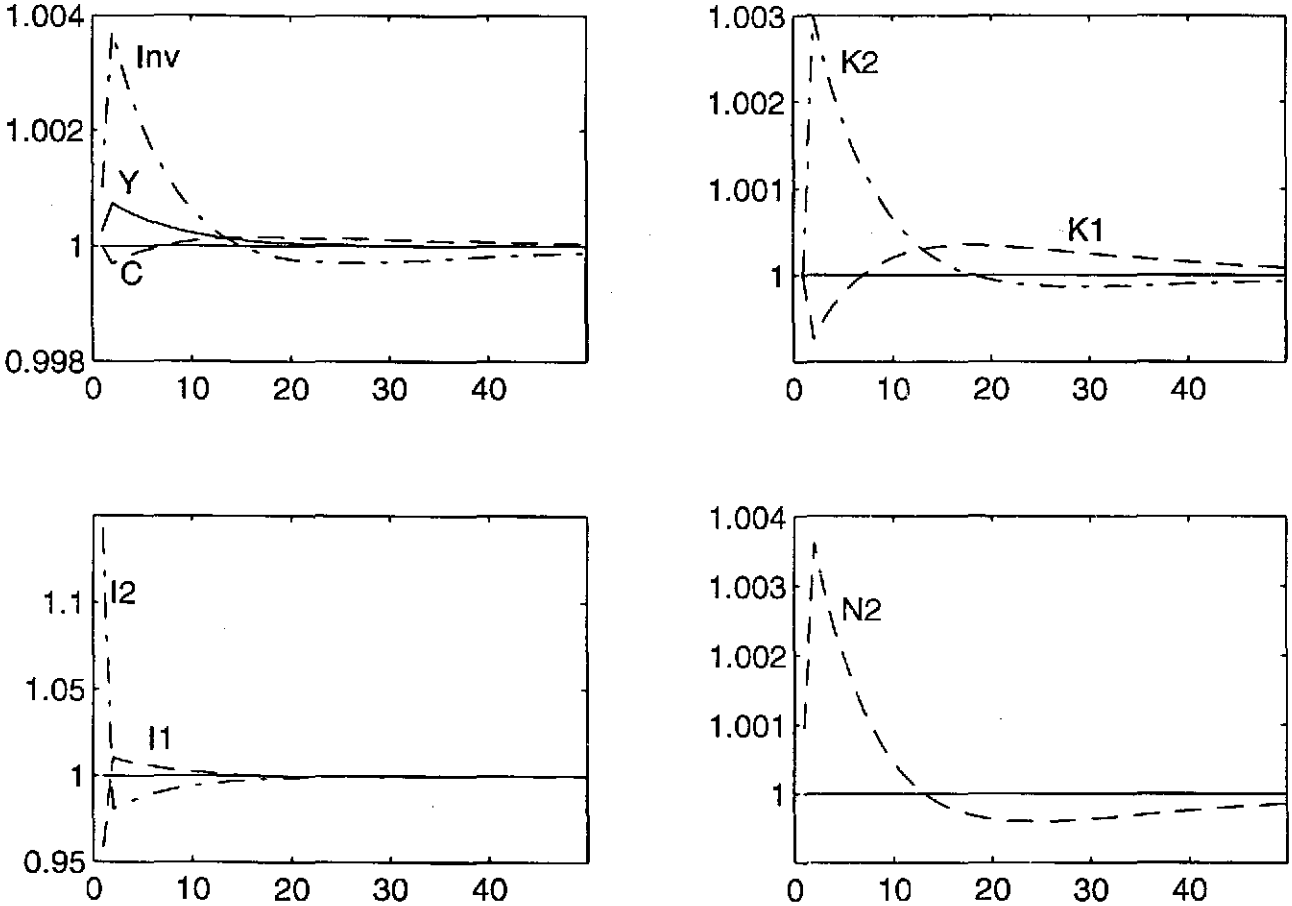


Figure 2



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K2
K1
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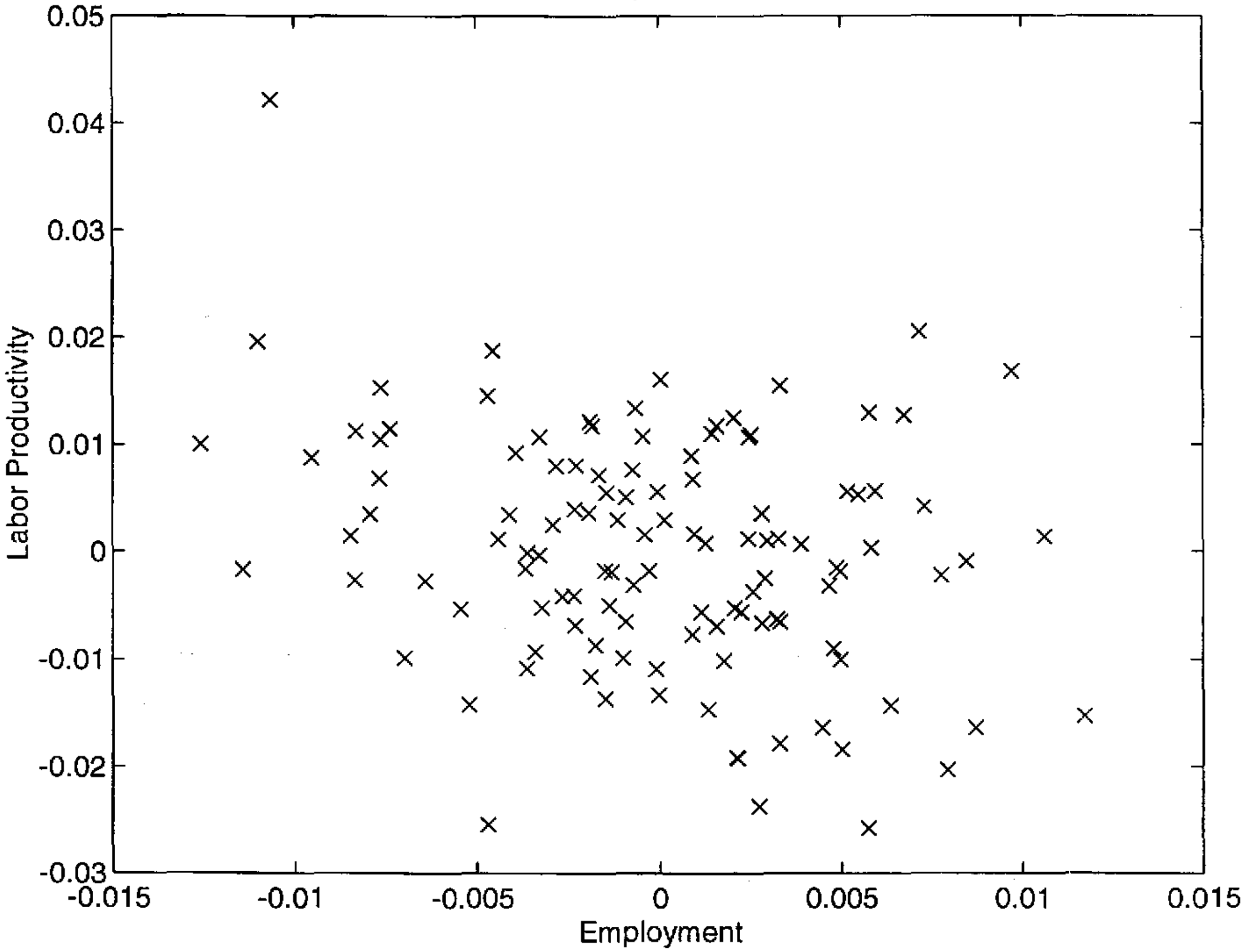
N2

Figure 3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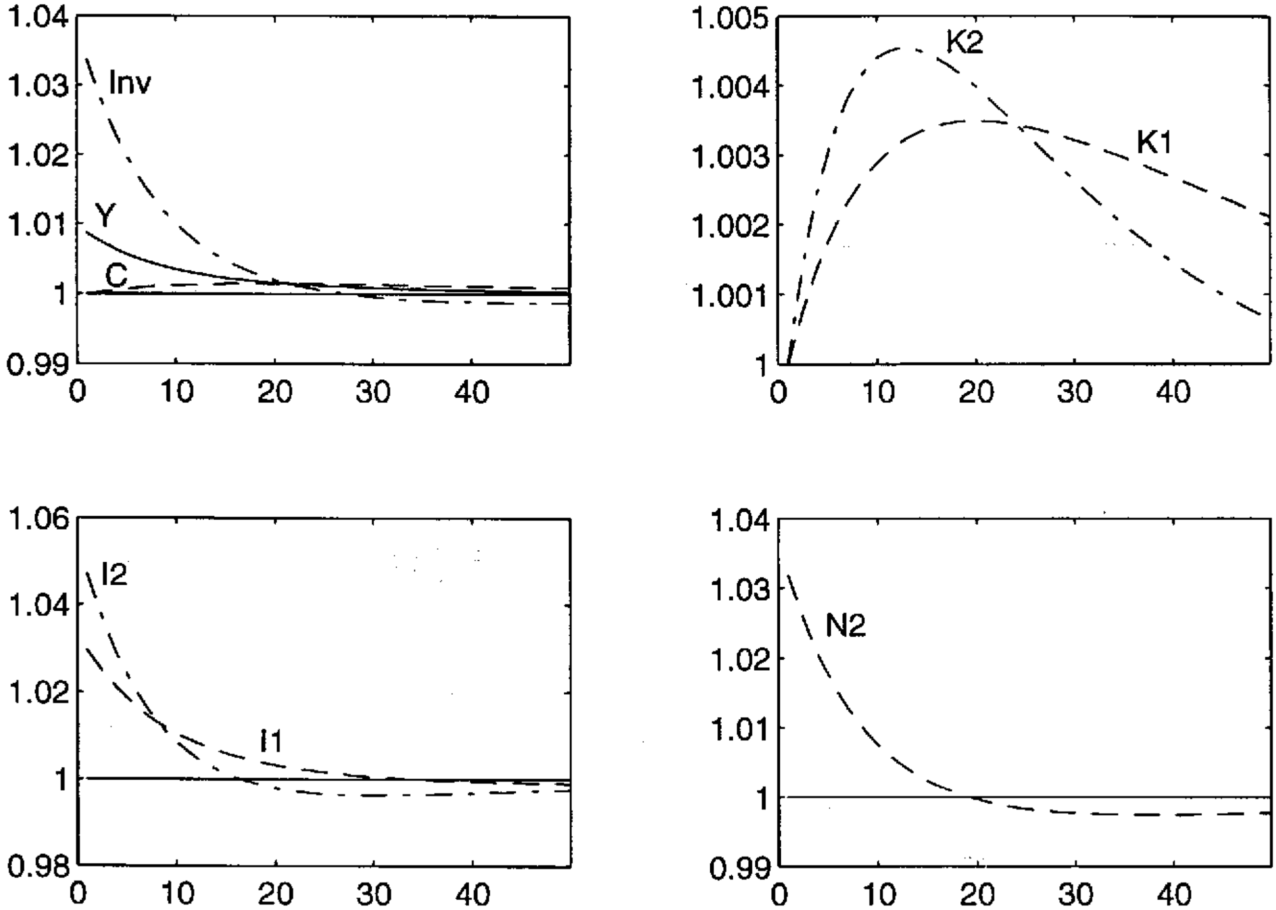
Employment

Figure 4



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1.003
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1.02
1.01
1
0.99

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