KEYNESIAN COORDINATION FAILURE AND PERSISTENCE

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ABSTRACT

Starting with the work of Diamond (1982), Hart (1982), Weitzman (1982), and Bryant (1983), a number of authors have employed models which exhibit potential coordination failure to show that many features of the Keynesian framework can be captured in models consistent with the microfoundations approach. In a recent paper Cooper and John (1988) argue that one property shared by many of these models is the presence of strategic complementarity, and that this is the critical feature which lies behind the finding of Keynesian type results. The current paper argues that the presence of strategic complementarity in the macro setting is potentially an important factor in explaining why the economy exhibits persistent responses to temporary shocks. That is, given the presence of any one of a variety of factors which would cause the economy not to instantaneously return to full employment after a temporary shock (e.g., adjustment costs associated with changing the capital stock), the persistence generated by a one time shock will be positively related to the degree of strategic complementarity in the environment.

I. Introduction

Starting with the work of Diamond (1982), Hart (1982), Weitzman (1982) and Bryant (1983), a number of authors have employed models which exhibit potential coordination failure to show that many features of the Keynesian framework can be captured in models consistent with the microfoundations approach.[1] For example, in the context of a search model Diamond demonstrates the existence of equilibria with "too low" a level of aggregative activity, Hart captures this feature and the simultaneous existence of multipliers in a model of monopolistic competition, while technological interactions are the crucial element of Bryant's analysis. One reason to refer to these seemingly diverse set of papers as a single literature is that all the models are in fact driven by the presence of the same factor. That is, as pointed out by Cooper and John (1988), all of the models are driven by the presence of strategic complementarity. A macroeconomic model which exhibits strategic complementarity is simply one where, the larger is aggregate production, the larger is the incentive for any particular agent to produce. Cooper and John first demonstrate that the presence of strategic complementarity is a characteristic of all of the models mentioned, and then go on to persuasively argue that this is the critical feature which lies behind the finding of Keynesian type results.

The major focus of the literature referred to above has been on three basic findings. First, the presence of strategic complementarity can result in an economy being characterized by multiple equilibria, where it is often possible to Pareto rank the various equilibria. Second, from a societal standpoint equilibria tend to be characterized by too low a level of aggregate activity. Third, strategic complementarity can cause an economy to be

characterized by multipliers very similar to those contained in old style Keynesian analysis.

While these results are certainly of interest, one shortcoming of the literature is that little attention has been paid to dynamic models characterized by strategic complementarity — especially models which exhibit anticipated or unanticipated shocks. This is an important omission in that, as opposed to what might have been true in the time of Keynes, the relevant public policy question is not whether the economy can become trapped in some type of "low level" equilibrium. Rather, the relevant concerns are first, what is the nature of the shocks which cause the economy to move away from full employment, and second, when a shock occurs what factors inhibit a quick return to the full employment state. This paper addresses the second of these issues in a dynamic model characterized by strategic complementarity. What we show is that the presence of strategic complementarity may itself be an important factor in explaining why the economy exhibits significant persistence in response to temporary shocks. That is, given the presence of any one of a variety of factors which would cause the economy not to instantaneously return to full employment after a temporary shock (e.g., adjustment costs associated with changing the capital stock), the persistence generated by a one time shock will be positively related to the degree of strategic complementarity in the environment.

The intuition behind this result is as follows. Suppose there is a temporary shock which causes aggregate production to fall below the full employment level. In most models where the economy does not immediately return to the full employment state, the speed of adjustment will depend in a negative fashion on the return each individual producer faces during the

adjustment phase of being below his own full employment production level. Given this, we can now consider the role played by strategic complementarity. Because the shock is followed by aggregate production falling below its full employment level, during the adjustment phase a representative producer will face a larger return for being below his own full employment production level the higher is the degree of strategic complementarity. The result is that the speed of adjustment is negatively related to the degree of strategic complementarity in the environment – or equivalently, the persistence generated by the shock is positively related to the degree of strategic complementarity.

There are a number of recent papers which are somewhat related. Cooper and Haltiwanger (1987) consider how an economy responds to sectoral shocks in a model characterized by strategic complementarity and inventories. However, rather than concentrating on how the amount of persistence generated by shocks is related to the degree of strategic complementarity in the environment, their focus is on the implications of the strategic complementarity approach for the co-movement of employment across sectors over the business cycle. Diamond and Fudenberg (1989) and Murphy, Shleifer and Vishny (1989b) consider dynamic models characterized by strategic complementarity and show that strategic complementarity can be important for the generation of aggregate fluctuations in the absence of shocks. They do not consider, however, how the degree of strategic complementarity affects the persistence of fluctuations which are caused by shocks. The final paper, which is quite a bit closer in terms of subject matter, is that of Haltiwanger and Waldman (1989). That paper considers a model wherein some agents are characterized by adaptive expectations while others are characterized by rational expectations, and

shows that the presence of strategic complementarity can be important for the generation of significant persistence. One way of viewing the current paper is that it generalizes one of the results of that earlier paper. The earlier paper showed that, in an environment where temporary shocks have long term effects because of the presence of agents with adaptive expectations, the persistence associated with temporary shocks will be positively related to the degree of strategic complementarity in the environment. This paper argues that, given the presence of any one of a variety of factors which would cause temporary shocks to have long term effects, there will be a positive relationship between persistence and the degree of strategic complementarity in the environment.[2]

The outline for the paper is as follows. Section II provides empirical evidence which supports both the presence of strategic complementarity in the macro environment, and the notion that temporary shocks are associated with significant persistence. Section III analyzes a model characterized by strategic complementarity and capital stock adjustment costs. Section IV discusses models which exhibit persistence for reasons other than the presence of capital stock adjustment costs. Section V presents some concluding remarks.

II. __Empirical Evidence__

Before proceeding to the theory, we present evidence which supports the empirical relevance of the issue under investigation. Although theoretical models based on the presence of strategic complementarity have been in the literature for a number of years, it is only recently that researchers have attempted to test for the presence of strategic complementarity in the macro environment. One of these recent studies is Oh and Waldman (1989). In this

section we present evidence similar to that presented in our earlier paper which strongly suggests that the macro economy is characterized by strategic complementarity. We also present related evidence which suggests that temporary shocks have persistent effects on the economy.[3]

Our test is based on revisions of the series of leading economic indicators. The logic behind the test is as follows. In a world characterized by strategic complementarity, agents should base their production plans for future quarters on what they think aggregate production in those future quarters will be. For example, one might conjecture that agents would look at the announcements of the leading economic indicators, and increase (decrease) their production plans when the announcement states that the value for the leading indicators is high (low). Now suppose the initial announcement of the leading indicators is high, but only because of an error associated with the original announcement. If strategic complementarity is present and agents are forecasting future production by looking at the leading indicators, then even erroneous forecasts should have effects on future growth. That is, to the extent that there are mistakes associated with the initial announcements of the leading indicators, these mistakes should be positively correlated with the future growth rate in output if strategic complementarity is present. This in turn implies that, since a positive (negative) revision of the leading indicators is equivalent to the statement that there was a negative (positive) mistake associated with the initial announcement, the finding of a negative correlation between revisions of the leading indicators and future growth in output would suggest that the macro economy is indeed characterized by strategic complementarity.

Table 1 reports results of a test of the above prediction for the time

period 1968-1988.[4] Consistent with the prediction, there is a negative correlation between revisions and the quarterly growth rate of industrial production for the third, fourth and fifth quarters after the initial announcement. Further, for the regression concerning the fourth quarter following the initial announcement, the coefficient on the revision variable is significant at the 99% level. Overall, our feeling is that the results reported provide quite strong evidence for the presence of strategic complementarity.

From the standpoint of the current paper, it is also of interest to see whether the expectational shocks measured by the revisions of the series of leading economic indicators have persistent effects on aggregate output. The reason is that these revisions must certainly represent temporary shocks. Consider the value for the leading indicators announced in January 1989. Since the final revision of that January number is announced in December 1989, the expectational shock measured by the cumulative revision of that Janaury number must be a temporary one. That is, the shock must be temporary since any misperception due to that original announcement will clearly have been eliminated within a time period of only one year.

We can thus test whether temporary shocks have persistent effects by investigating over what time period revisions of the series of leading economic indicators have a negative correlation with aggregate output. Table 1 suggests that errors in the series of leading economic indicators begin to have an impact on the growth of industrial production in the third quarter following the initial announcement. To test for persistence we therefore take as our starting point the value for industrial production at the beginning of the third quarter following the initial announcement, and

see over what time period revisions have a negative correlation with the
growth rate defined from that starting point. In table 2 we conduct exactly
this test for the time period up to 32 quarters following the initial
announcement, where ΔIP_{t+2+j} denotes the growth in industrial production from
the beginning of the third quarter following the initial announcement to the
end of the $(2+j)$th quarter. For each regression the only explanatory variables
are the true value for the leading indicators in quarter t and quarter t's
revision, i.e., no later values for the leading indicators or the revisions
are included. What the table indicates is that these temporary shocks have
quite persistent effects. Seven years after the initial announcement (and six
years after the final revision is announced) the revision still has a
statistically significant and large correlation with the level of industrial
production.[5]

III. A Model With Capital Stock Adjustment Costs

In the previous section we presented evidence which suggests that
strategic complementarity is present in the macro environment, and that
temporary shocks have persistent effects on aggregate output. In this section
we formally demonstrate that the presence of strategic complementarity may
itself be an important factor in explaining why there is persistence in
response to temporary shocks.

A. The Model

In this sub-section we construct a simple macroeconomic model similar to
one analyzed in Haltiwanger and Waldman (1989). The main differences are
first that all agents here are assumed to have rational expectations, and
second, that agents (i.e., firms) now face adjustment costs for changing their

capital stock.

Consider a continuum of risk neutral agents distributed in the unit interval who in each period must decide on an output level. Let $y_{i,t}$ denote agent i's production level in period t. The cost to agent i of producing $y_{i,t}$ is denoted $c_{i,t}$, where $c_{i,t} = (y_{i,t})^2/(1+k_{i,t})$. The term $k_{i,t}$ is the size of agent i's capital stock in period t. The specification therefore states that the larger is the period t capital stock, the smaller is the period t cost of producing any fixed output level. The manner in which $k_{i,t}$ is determined is described below.

Let Y_t be period t's aggregate production. The gross return to an agent for producing an amount y_t is given by $r(Y_t)y_t$, where $r'>0$. The assumption $r'>0$ means that the environment exhibits strategic complementarity, i.e., an increase in aggregate production raises the incentive for each individual agent to produce.[6]

Given the assumption $r'>0$, this model can be interpreted in terms of a number of the existing macroeconomic models of coordination failure which were discussed in the introduction. For example, consider Diamond (1982). In that model the key restriction on behavior is that each individual is better off trading rather than consuming what he himself produces. Under this interpretation, $r'>0$ indicates the presence of positive trading externalities. That is, the larger is aggregate production, the higher is the probability that any particular trader will successfully complete a trade.

One can also interpret $r'>0$ as arising from demand linkages between imperfectly competitive producers in a multisector economy (see for example Hart (1982)). Under this interpretation, $r(Y_t)$ denotes the marginal revenue from undertaking a production project, and $r'>0$ indicates that demand linkages

cause the marginal revenue function facing a producer in a particular sector to shift out as the output of other sectors increase.

We now discuss the determination of $k_{i,t}$. Agent i must split his net return in each period between consumption and investment, where for simplicity it is assumed that it takes one period to construct capital. To be specific, $k_{i,t}$ is given by

$$(1) \qquad k_{i,t+1} = \delta k_{i,t} + \mu_{t+1} m(w_{i,t}),$$

where $(1-\delta)$ is a depreciation term and thus falls in the interval $(0,1)$, while $w_{i,t}$ is agent i's expenditure on investment in period t.[7] It is assumed that a firm faces adjustment costs for changing its capital stock, i.e., $m(0)=0$, $m'(0)=\infty$, and $m'(w)>0$, $m''(w)<0$ for all $w>0$. The term μ_{t+1} is a parameter shared by all the agents which captures the productivity of investing in capital. It is assumed that each agent's objective in choosing his expenditures on capital is to maximize the discounted expected value of his consumption stream, where each agent discounts the future by a factor β.

Because of the presence of strategic complementarity, the model described above may display multiple steady state equilibria. Since we want to abstract away from this possibility we impose the following conditions:

$$(2) \qquad r'(Y(k))(1+k)<2 \quad \text{for all } k\geq 0$$

and

$$(3) \qquad \frac{2(1-\delta)(1-\beta\delta)}{\beta\mu^2} > \frac{r(Y(k))^2 r'(Y(k))}{n''(\frac{k-\delta k}{\mu})(2-r'(Y(k))(1+k))} \quad \text{for all } k\geq 0,$$

where $Y(k)$ is defined by the equation $Y(k)/r(Y(k))=(1+k)/2$ for all $k\geq 0$. Equation (2) guarantees that for a fixed value of k, the resulting value for Y is unique. Equation (3) ensures that in the aggregate the return to investing in capital is sufficiently concave to guarantee a unique and stable

steady state equilibrium.

B. Analysis

As indicated, the focus of the analysis is on how the economy responds to temporary shocks and, in particular, on how the persistence generated by temporary shocks is related to the degree of strategic complementarity in the environment. We will consider shocks to the productivity of capital investment which are captured by changes in μ_t. Below $Y^S(\bar{\mu})$ will denote the steady state value for Y when $\mu_t = \bar{\mu}$ in every period.

We begin by investigating how our model economy responds to a temporary shock similar to the type of shock considered in section II. That is, we want to capture how the economy responds to a shock which takes the form of information concerning the future aggregate state of the world, where there is some probability the information is inaccurate. In proposition 1 we thus consider the response of the economy to a shock of the following form. It is assumed that up to period T-2 the economy is in a steady state where $\mu = \bar{\mu}$. In period T-1 all the agents receive information stating that $\mu_t = \bar{\mu}$ for all periods except T, while $\mu_T = \tilde{\mu}$. All the agents know, however, that the information is only correct with probability p, and that there is a probability (1-p) that $\mu_t = \bar{\mu}$ for all periods. Below $\dot{Y}_t$ denotes aggregate output in period t when $\mu_T = \tilde{\mu}$, while $\tilde{Y}_t$ denotes aggregate output in period t when $\mu_t = \bar{\mu}$. Note, all proofs are contained in the Appendix.

Proposition 1: If $\tilde{\mu}>(<)\bar{\mu}$, then

    i) $\dot{Y}_T>(<)\dot{Y}_{T+1}>(<)\dot{Y}_{T+2}>(<)\ldots$

    ii) $\tilde{Y}_T>(<)\tilde{Y}_{T+1}>(<)\tilde{Y}_{T+2}>(<)\ldots$

    iii) $\tilde{Y}_t>(<)\dot{Y}_t$ for all $t\geq T$

    iv) $\lim\limits_{t\to\infty}\dot{Y}_t = \lim\limits_{t\to\infty}\tilde{Y}_t = Y^S(\bar{\mu})$

Proposition 1 states that in response to an announcement of a one time shock this model exhibits persistence, i.e., the economy only slowly returns to the original steady state production level. What happens is that the shock causes the capital stock to change because agents alter their investment plans, and for the case $\mu_t=\tilde{\mu}$ also because of a direct change in the productivity of investing in capital. In turn, the changed values for capital stock holdings lead to persistent changes in aggregate output, where the persistence is greater for the case $\mu_t=\tilde{\mu}$ because of the direct change in the productivity of investing.

Proposition 1 is not very surprising. Given the specification of the function m(.), i.e., that agents face adjustment costs for changing their capital stock, it would only have been surprising if the model did not exhibit persistence in response to the type of announcement considered (see Lucas (1977) for an earlier discussion concerning capital stock adjustment costs and persistence). We now turn our attention to the more interesting question which concerns the amount of persistence generated by a one time shock. In particular, we focus on the relationship between the amount of persistence generated and the degree of strategic complementarity in the environment. In order to investigate this issue we characterize a transfor-

mation of $r(.)$ that increases the degree of strategic complementarity. Suppose $\hat{r}(Y^*)=r(Y^*)$. Then $\hat{r}(.)$ represents an increase in the degree of strategic complementarity if $\hat{r}'(Y)>r'(Y)$ for all Y. In other words, an increase in the degree of strategic complementarity involves an increase in the slope of $r(.)$ around some fixed point.

<u>Proposition 2</u>: Suppose the economy experiences the type of temporary shock considered in proposition 1. A transformation of $r(.)$ which increases the degree of strategic complementarity but leaves $Y^S(\bar{\mu})$ unchanged will cause both $\left|\check{Y}_t - Y^S(\bar{\mu})\right|$ and $\left|\tilde{Y}_t - Y^S(\bar{\mu})\right|$ to increase for every $t \geq T$.

Proposition 2 demonstrates the main point of the paper. The persistence generated by a temporary shock is a positive function of the degree of strategic complementarity in the environment. The logic behind this result is as follows. Suppose there is a shock which causes capital stock holdings in period T to fall below their steady state values. We can think about the incentive an agent faces during the adjustment phase for investing so as to quickly return to the steady state value. Since during the adjustment phase aggregate production is below its steady state value, this incentive will be negatively related to the degree of strategic complementarity in the environment. In turn, since the incentive for investing is reduced by an increase in strategic complementarity, we find that an increase in strategic complementarity serves to increase the persistence generated by the shock.

Another way of thinking about this result is in terms of the more general intuition given in the introduction. Consider again a temporary shock which pushes aggregate production below its steady state level. In this model (as well as the models discussed in the following section), the speed of adjustment

back to the steady state level depends in a negative fashion on the return each individual producer faces during the adjustment phase of being away from his own steady state production level. Notice, however, since the shock is followed by aggregate production falling below its own steady state level, during the adjustment phase a representative producer will face a higher return for being below his own steady state level the higher is the degree of strategic complementarity. The result is that the speed of adjustment is negatively related to the degree of strategic complementarity in the environment — or equivalently, the persistence generated by the shock is positively related to the degree of strategic complementarity.

One question the reader might have at this point is to what extent are our results dependent on the type of temporary shock considered. To this point we have confined the analysis to what would best be described as an anticipated shock, i.e., agents receive information concerning the potential change in fundamentals prior to the change taking effect. The question of interest, therefore, is whether our results concerning the relationship between strategic complementarity and persistence extend to the case where the shock is unanticipated.

In proposition 3 we consider the response of the economy to an unanticipated shock. It is assumed that up to period T-2 the economy is in a steady state where $\mu = \bar{\mu}$. In period T-1 the agents choose expenditures on capital assuming that the economy will remain in the steady state. In fact, however, $\mu_T = \tilde{\mu}$, and the agents only find this out in period T. Finally, for every period subsequent to T it is the case that $\mu_t = \bar{\mu}$, and agents make their investment decisions in those periods knowing this is the case.

<u>Proposition 3</u>: If $\bar{\bar{\mu}} > (<)\bar{\mu}$, then

    i) $Y_T > (<) Y_{T+1} > (<) Y_{T+2} > (<) \ldots$

    ii) $\lim_{t \to \infty} Y_t - Y^S(\bar{\mu})$.

Proposition 3 tells us that in this model an unanticipated shock works in a fashion quite similar to the anticipated case considered in proposition 1. That is, an unanticipated shock causes a change in the capital stock and because of adjustment costs there is only a slow return back to the steady state.

We can now consider the relationship between strategic complementarity and persistence in an environment characterized by an unanticipated shock.

<u>Proposition 4</u>: Suppose the economy experiences the type of temporary shock considered in proposition 3. A transformation of r(.) which increases the degree of strategic complementarity but leaves $Y^S(\bar{\mu})$ unchanged will cause $\left| Y_t - Y^S(\bar{\mu}) \right|$ to increase for every t≥T.

Proposition 4 tells us that our earlier result was not at all dependent on the fact we considered an anticipated shock. Whether or not the shock is anticipated or unanticipated, as long as some persistence will be generated, the amount of persistence generated is positively related to the degree of strategic complementarity in the environment.

IV. <u>Other Factors Which Generate Persistence</u>

In the previous section we considered a model where agents face adjustment costs for changing their capital stock, and demonstrated that the presence of strategic complementarity may be an important factor in explaining why the

economy exhibits significant persistence in response to temporary shocks. In this section we argue that this conclusion is quite general. That is, given the presence of any one of a variety of factors which would cause the economy not to instantaneously return to full employment after a temporary shock, the presence of strategic complementarity may be important for understanding why the economy exhibits significant persistence. In what follows, so as to avoid potential redundancy with propositions derived in the previous section, the argument will proceed on an informal rather than on a formal basis.

A. Adaptive Expectations

One reason other than capital stock adjustment costs for why an economy may exhibit persistence is because some or all of the agents are characterized by adaptive expectations. This factor was analyzed in Haltiwanger and Waldman (1989). In particular, they considered a variant of the model of the previous section wherein a subset of agents form their expectations for $r(Y_t)$ in an adaptive fashion, and capital is not part of the production process. Consistent with the findings of the previous section, they found that an increase in the degree of strategic complementarity serves to increase the persistence generated by temporary shocks.

One can understand their result by considering an economy populated solely by agents with adaptive expectations. Suppose that in such an economy there is a temporary shock which causes $r(Y_T)$ to fall below its steady state value by some fixed amount. This will lower the expectation agents have for $r(Y_{T+1})$, which in turn will reduce aggregate output in T+1. However, for any fixed decrease in output in T+1, the realized value for $r(Y_{T+1})$ will be smaller the higher is the degree of strategic complementarity. What this implies is that, since the realized value for $r(Y_{T+1})$ affects the expectation agents have

for $r(Y_{T+2})$, aggregate output in period T+2 will be smaller the higher is the degree of strategic complementarity. In turn, continuously repeating this argument one finds that, for every t≥T+2, the deviation from steady state output will be higher the higher is the degree of strategic complementarity.

B. Sticky Prices

Another factor frequently used to generate persistence is the existence of sticky prices. This notion has been formalized in the literature in a number of different ways. For example, the idea of prices being set in a staggered fashion goes back to the work of Fischer (1977) and Taylor (1980), menu costs have been explored in the work of Mankiw (1985) and Akerlof and Yellen (1985), while more recently attention has focused on whether sticky prices arise in models where the timing of price changes is assumed to be endogenous (see Ball and Romer (1987) and Ball and Cecchetti (1988)). In this sub-section we argue that, if persistence arises because of sticky prices of one type or another, the persistence generated by a shock will be positively related to the degree of strategic complementarity.

We put forth our argument in the context of a monopolistic competition model where price setting is staggered, i.e., half the firms set their prices every even period while the other half set their prices every odd period. We also assume that the economy exhibits strategic complementarity in prices — that is, a firm's optimal price is an increasing function of the aggregate price level.[8] Starting from a steady state, consider how this economy responds to a one time unanticipated increase in the money supply which occurs in say period T. Group A will refer to the set of firms which set their prices in periods T, T+2, T+4, etc., while group B will refer to the set of firms which set their prices in periods T+1, T+3, etc. In period T+1 group B firms

will want to increase their prices, but not all the way to the new steady state levels. The reason is that in period T+1 group A firms will remain at the old steady state prices, and given strategic complementarity this provides an incentive for the group B firms to only partially adjust. Further, the higher is the degree of strategic complementarity the higher will be the incentive for group B firms to only partially adjust, and thus the lower will be the prices set by group B firms in period T+1. In turn, repeating this argument for periods T+2, T+3, etc., one has that for every t≥T+1, the difference between the actual price level and the eventual steady state price level will be an increasing function of the degree of strategic complementarity in the environment. In other words, just as was true under the capital stock adjustment cost assumption and the adaptive expectations assumption, the persistence generated by a one time shock is positively related to the degree of strategic complementarity.

Finally, although the argument above is put forth in the context of a specific model of sticky prices, our conjecture is that the result is quite general. That is, given almost any reasonable specification under which sticky prices lead to persistent responses, our conjecture is that the magnitude of the persistence will be positively related to the degree of strategic complementarity.

C. Other Types of Adjustment Costs

As a final point, we would like to make clear that although the formal model of section III focuses on adjustment costs associated with a firm changing its capital stock, the argument applies much more generally. In particular, similar to our conjecture above concerning sticky price models, our feeling is that almost any adjustment cost model consistent with

persistence will be such that the persistence generated by a temporary shock will be positively related to the degree of strategic complementarity in the environment.

Consider for example a model of monopolistic competition and inventories, where each firm faces adjustment costs for changing its level of inventory holdings. Suppose further that in period T there is a temporary shock to the economy which causes aggregate inventory holdings to rise. Blinder and Fischer (1981) consider just such a model and demonstrate that the response of the economy to this temporary shock will be an immediate fall in aggregate output, and then a gradual return to the original steady state level. We can now consider the role that strategic complementarity would play in such an environment. Consider period T+1. Since during the adjustment phase aggregate production is below its steady state value, in period T+1 the incentive to produce will be smaller the larger is the degree of strategic complementarity. In addition, since the incentive to run down excess inventories is positively related to the incentive to produce, there will also be a negative relationship between the incentive to run down inventories and the degree of strategic complementarity. The result is that aggregate output in period T+1 will be negatively related to the degree of strategic complementarity, while aggregate inventory holdings at the end of period T+1 will be positively related to the degree of strategic complementarity. In turn, repeating this argument for periods T+2, T+3, etc., yields that, just as was true for the capital stock adjustment cost model of section III, for every t≥T+1 the deviation from steady state behavior will be positively related to the degree of strategic complementarity in the environment.

V. Conclusion

The presence of strategic complementarity in macroeconomic models has been used to explain a host of important phenomena, e.g., multipliers, multiple equilibria, and the possibility of underemployment equilibria. The literature has paid little attention, however, to dynamic models characterized by strategic complementarity — especially models which consider how an economy responds to anticipated and unanticipated shocks. This is an important omission in that two of the more important public policy issues are first, what is the nature of the shocks which cause the economy to move away from full employment, and second, when a shock occurs what factors inhibit a quick return to the full employment state. This paper addresses the second of these issues in a dynamic model characterized by strategic complementarity. What the analysis demonstrates is that the presence of strategic complementarity may itself be an important factor in understanding why the economy exhibits significant persistence in response to temporary shocks. That is, given the presence of any one of a variety of factors which would cause the economy not to instantaneously return to full employment after a temporary shock, the persistence generated by a one time shock will be positively related to the degree of strategic complementarity in the environment.

One way in which the analysis of this paper might fruitfully be extended is to consider the concept of the automatic stabilizer. In an earlier literature on economic fluctuations the concept of the automatic stabilizer was a central element for explaining why the post World War II economy seems to be less prone to large fluctuations than the pre World War II economy. The logic was that there were changes in the system of governing, e.g., changes in the tax system, which reduced the instability the economy exhibits in response

to shocks. Our claim is that the concept of the automatic stabilizer can be at least partially understood in terms of the analysis of the current paper. Specifically, our analysis suggests that any change which serves to reduce the degree of strategic complementarity should be a type of automatic stabilizer. This follows from our finding that the persistence generated by temporary shocks is positively related to the degree of strategic complementarity in the environment. In other words, exactly consistent with the definition of an automatic stabilizer, any change which reduces the degree of strategic complementarity should reduce the instability the economy exhibits in response to shocks. In future work we hope to more fully investigate this idea. In particular, our plan is to formally investigate the links between strategic complementarity and those aspects of the post World War II economy that earlier authors have identified as automatic stabilizers.

Appendix

Proof of Proposition 1: To prove proposition 1 we must first demonstrate
that the economy is characterized by a unique and stable steady state
equilibrium. Since we assume a continuum of agents in the unit interval,
total output as a function of the period t capital stock, $Y(k_t)$, is defined
by the expression $Y(k_t)/r(Y(k_t))=(1+k_t)/2$. This follows from each agent
producing to the point where the marginal cost of production equals the
marginal revenue of production. Given a fixed value for k_t, we now have that
equation (2) is a sufficient condition for a unique Y_t.

The representative agent solves the following maximization problem.

(A1)
$$\max_{k_{t+1}, c_t, w_t} \Sigma \beta^t c_t$$

$$\text{s.t.} \quad k_{t+1}=\delta k_t + \mu_{t+1} m(w_t)$$

$$r(Y_t)y_t = c_t + w_t + y_t^2/(1+k_t)$$

Let $n=m^{-1}$. Since $m'>0$ and $m''<0$, we have that $n'>0$ and $n''>0$. (A1) can be
rewritten as

(A2)
$$\max_{\{k_{t+1}\}} \Sigma\beta^t[r(Y_t)^2(1+k_t)/4 - n(\frac{k_{t+1}-\delta k_t}{\mu_{t+1}})].$$

It is easily demonstrated that (A2) is a well defined dynamic optimization
problem, and thus sufficient conditions for an interior solution are the Euler
equation and the transversality condition.

(A3)
$$- \frac{1}{\mu_{t+1}} n'(\frac{k_{t+1}-\delta k_t}{\mu_{t+1}}) + \beta[r(Y_{t+1})^2/4 + \frac{\delta}{\mu_{t+2}} n'(\frac{k_{t+2}-\delta k_{t+1}}{\mu_{t+2}})]=0$$

(A4)
$$\lim_{t\to\infty} \beta^t[r(Y_t)^2/4 + \frac{\delta}{\mu_{t+1}} n'(\frac{k_{t+1}-\delta k_t}{\mu_{t+1}})]k_t=0$$

Note that for deriving the equations above the representative agent takes the sequence of Y_t's as given, rather than as a function of his own actions. Equations (A3) and (A4) yield that there exists a unique steady state which is defined by (A5), where k^* denotes the steady state value of the capital stock.

$$(A5) \qquad (1-\beta\delta)n'(\frac{(1-\delta)k^*}{\bar{\mu}}) - \bar{\mu}\beta r(Y(k^*))^2/4$$

Given $n'(0)=0$ and $r(0)>0$ (see footnote 6), (A5) yields that $k^*>0$.

To consider stability we first take a linear approximation of the Euler equation around k^*.

$$(A6) \qquad -\frac{1}{\beta}(k_t-k^*) + (\frac{1}{\beta\delta} + \delta - \frac{\bar{\mu}^2 r^2 r'}{\delta n''(4-2r'(1+k^*))})(k_{t+1}-k^*)-(k_{t+2}-k^*) - 0$$

Rewriting (A6) we obtain

$$(A7) \qquad \begin{bmatrix} k_{t+2} \\ k_{t+1} \end{bmatrix} - A \begin{bmatrix} k_{t+1} \\ k_t \end{bmatrix} - \begin{bmatrix} \frac{1}{\beta\delta} + \delta - \frac{\bar{\mu}^2 r^2 r'}{\delta n''(4-2r'(1+k^*))} & -\beta^{-1} \\ 1 & 0 \end{bmatrix} \begin{bmatrix} k_{t+1} \\ k_t \end{bmatrix}.$$

The characteristic polynomial for A is

$$(A8) \qquad \lambda^2 - (\frac{1}{\beta\delta} + \delta - \frac{\bar{\mu}^2 r^2 r'}{\delta n''(4-2r'(1+k^*))})\lambda + \frac{1}{\beta} - 0.$$

It is clear that equation (3) is sufficient for one of the roots to lie between zero and one. The other root exceeds one. Thus by Theorem 6.9 in Stokey and Lucas (1989) the above steady state is stable. Also, the fact that $0<\lambda_1<1$ implies that adjustment paths are monotonic. Finally, λ_1 is given by equation (A9).

$$(A9) \qquad \lambda_1 - \frac{1}{2}(\frac{1}{\beta\delta} + \delta - x - [(\frac{1}{\beta\delta} + \delta - x)^2 - \frac{4}{\beta}]^{1/2},$$

$$\text{where } x - \frac{\bar{\mu}^2 r^2 r'}{\delta n''(4-2r'(1+k^*))}.$$

We can now prove proposition 1. Suppose $\tilde{\mu} > \bar{\mu}$. The expected value of μ, $\mu^E = p\tilde{\mu} + (1-p) > \bar{\mu}$. After some calculation, (A3), $n = m^{-1}$, and $0 < \lambda_1 < 1$, yields $\partial w_t / \partial \mu_{t+1} > 0$. Thus $k_T > k^*$. Since $\partial Y_t / \partial k_t = r/(2 - r'(1+k_t)) > 0$, this in combination with a monotonic adjustment path yields i). ii) follows similarly with the only difference being that the changed value for μ causes an extra increase in k_T. iii) is straightforward. w_{T-1} is chosen before μ_T is realized and thus does not depend on the realization. This implies k_T will be higher if $\tilde{\mu}$ is realized rather than $\bar{\mu}$. iii) then follows from the fact that $\partial Y_t / \partial k_t > 0$ and the monotonic adjustment path. iv) follows immediately since the steady state is unique and stable.

The case $\tilde{\mu} < \bar{\mu}$ follows similarly.

Proof of Proposition 2: (A3) and (A9) yield

$$\text{(A10)} \qquad \frac{\partial k_{t+1}}{\partial \mu_{t+1}} = \frac{2[(n'/n'') + (1/\mu_{t+1})]}{1 - \beta\delta x + \beta\delta^2 + ((1+\beta\delta^2 - \beta\delta x)^2 - 4\beta\delta^2)^{1/2}} ,$$

where x is defined as in (A9). Suppose $\tilde{\mu} > \bar{\mu}$. Let $\hat{x}$ be the value for x when the degree of strategic complementarity increases to $\hat{r}$. Since $\hat{r}(Y) > r(Y)$ and $\hat{r}'(Y) > r'(Y)$ when $Y > Y^S$, we have that $\hat{x} > x$. (A10) in turn implies that $\hat{k}_T > k_T$, while (A9) implies $\hat{\lambda}_1 > \lambda_1$. Together with $\partial Y_t / \partial k_t > 0$, this completes the proof for this case. The other case follows similarly.

Propositions 3 and 4: The proofs of these propositions are identical to the proofs of propositions 1 and 2 except that agents now choose w_{T-1} given a belief that $\mu_T = \bar{\mu}$.

Footnotes

[1]Later papers include Howitt (1985), Heller (1986), Schleifer (1986), Blanchard and Kiyotaki (1987), Cooper and Haltiwanger (1987), Roberts (1987), Cooper and John (1988), Kiyotaki (1988), Schleifer and Vishny (1988), Summers (1988), Diamond and Fudenberg (1989), Haltiwanger and Waldman (1989), and Murphy, Shleifer and Vishny (1989a,b). See also Leijonhufvud (1981) for a non-technical analysis which captures many of the same ideas.

[2]Haltiwanger and Waldman (1989) also show that, given the presence of strategic complementarity, at least for the first few periods which follow a shock it will be the agents with adaptive expectations who are disproportionately important. That is, at least for the first few periods, the deviation from steady state behavior will be more than that suggested by the number of agents with adaptive expectations in the population. See also Haltiwanger and Waldman (1985).

[3]Results similar to those reported here are contained in our earlier paper with the only difference being that the data analyzed here concerns a longer time period.

[4]The revisions utilized for our tests are not the cumulative revisions of the leading indicators, but rather the cumulative revisions minus the first two monthly revisions. See Oh and Waldman (1989) for why this is the relevant measure.

[5]Because of the overlapping nature of the dependent variable, the t-statistics reported in table 2 are biased upward. Further, since the results in table 2 could be affected by the presence of autocorrelation, it is worth noting that there is little or no autocorrelation among the revisions.

[6]To rule out the possibility of a degenerate equilibrium where the

capital stock equals zero we impose the condition $r(0)>0$. One can interpret $r(0)$ as being the gross return from a unit of output when an individual is unable to trade. Hence, $r(0)>0$ simply states there is a positive return derived from consuming one's own production.

[7]Introducing a time build assumption would serve to complicate the analysis without changing the qualitative nature of the results.

[8]Ball and Romer (1987) show that if the timing of pricing decisions were made endogenous in this type of model, then price setting would not be staggered. However, Ball and Cecchetti (1988) demonstrate that staggered price setting would arise if imperfect information were added to the model.

References

Akerlof, G., and J. Yellen, "The Macroeconomic Consequences of Near-Rational Rule-of-Thumb Behavior," <u>Quarterly Journal of Economics</u>, 100 (Supplement 1985), 823-838.

Ball, L., and S. Cecchetti, "Imperfect Information and Staggered Price Setting," <u>American Economic Review</u>, 78 (December 1988), 999-1018.

_____, and D. Romer, "The Equilibrium and Optimal Timing of Price Changes," NBER Working Paper No. 2412, October 1987.

Blanchard, O., and N. Kiyotaki, "Monopolistic Competition and the Effects of Aggregate Demand," <u>American Economic Review</u>, 77 (September 1987), 647-666.

Blinder, A., and S. Fischer, "Inventories, Rational Expectations, and the Business Cycle," <u>Journal of Monetary Economics</u>, 8 (November 1981), 277-304.

Bryant, J., "A Simple Rational Expectations Keynes-Type Model," <u>Quarterly Journal of Economics</u>, 98 (August 1983), 525-529.

Cooper, R., and J. Haltiwanger, "Inventories and the Propagation of Sectoral Shocks," NBER Working Paper No. 2425, November 1987.

_____, and A. John, "Coordinating Coordination Failures in Keynesian Models," <u>Quarterly Journal of Economics</u>, 103 (August 1988), 441-463.

Diamond, P., "Aggregate Demand Management in Search Equilibrium," <u>Journal of Political Economy</u>, 90 (October 1982), 881-894.

_____, and D. Fudenberg, "Rational Expectations Business Cycles in Search Equilibrium," <u>Journal of Political Economy</u>, 97 (June 1989), 606-619.

Fischer, S., "Long Term Contracts, Rational Expectations, and the Optimal Money Supply Rule," <u>Journal of Political Economy</u>, 85 (February 1977),

163-190.

Haltiwanger, J., and M. Waldman, "Rational Expectations and the Limits of Rationality: An Analysis of Heterogeneity," American Economic Review, 75 (June 1985), 326-340.

_____, "Limited Rationality and Strategic Complements: The Implications for Macroeconomics," Quarterly Journal of Economics, 104 (August 1989), 463-483.

Hart, O., "A Model of Imperfect Competition with Keynesian Features," Quarterly Journal of Economics, 97 (February 1982), 109-138.

Heller, W., "Coordination Failure under Complete Markets with Applications to Effective Demand," in Equilibrium Analysis: Essays in Honor of Kenneth J. Arrow, Volume II, Walter P. Heller, Ross M. Starr, and David A. Starrett, eds. (Cambridge: Cambridge University Press, 1986).

Howitt, P., "Transaction Costs in the Theory of Unemployment," American Economic Review, 75 (March 1985), 88-100.

Kiyotaki, N., "Multiple Expectational Equilibria under Monopolistic Competition," Quarterly Journal of Economics, 103 (November 1988), 695-713.

Leijonhufvud, A., Information and Coordination: Essays in Macroeconomic Theory, (New York: Oxford University Press, 1981).

Lucas, R., "Understanding Business Cycles," in Stabilization of the Domestic and International Economy, K. Brunner and A. Meltzer eds., 1977, 7-29.

Mankiw, N.G., "Small Menu Costs and Large Business Cycles," Quarterly Journal of Economics, 100 (May 1985), 529-537.

Murphy, K., A. Shleifer, and R. Vishny (1989a), "Building Blocks of Market Clearing Business Cycle Models," mimeo, University of Chicago, April 1989.

_____ (1989b), "Increasing Returns, Durables

and Economic Fluctuations," mimeo, University of Chicago, April 1989.

Oh, S., and M. Waldman, "The New Perspective on Keynesian Coordination Failure: Theory and Evidence," UCLA Working Paper No. 559, May 1989.

Roberts, J., "An Equilibrium Model with Involuntary Unemployment at Flexible Competitive Prices and Wages," American Economic Review, 77 (December 1987), 856-874.

Shleifer, A., "Implementation Cycles," Journal of Political Economy, 94 (December 1986), 1163-1190.

_____, and R. Vishny, "The Efficiency of Investment in the Presence of Aggregate Demand Spillovers," Journal of Political Economy, 96 (December 1988), 1221-1231.

Stokey, N., and R. Lucas, Recursive Methods in Economics, (Cambridge: Harvard University Press, 1989).

Summers, L., "Relative Wages, Efficiency Wages, and Keynesian Unemployment," American Economic Review, 78 (May 1988), 383-388.

Taylor, J., "Aggregate Dynamics and Staggered Contracts," Journal of Political Economy, 88 (February 1980), 1-23.

Weitzman, M., "Increasing Returns and the Foundations of Unemployment Theory," Economic Journal, 92 (1982), 787-804.

Table 1

THE IMPACT OF THE CUMULATIVE REVISION (MINUS THE FIRST

QUARTERLY REVISION) OF THE LEADING INDICATORS[*]

j	b_1	b_2	b_3	Adjusted R^2
1	.005 (2.20)	.393 (5.68)	.341 (3.21)	.49
2	.004 (1.70)	.313 (3.60)	.108 (.81)	.20
3	.004 (1.33)	.198 (2.06)	-.230 (1.57)	.04
4	.004 (1.40)	.128 (1.35)	-.398 (2.75)	.07
5	.006 (2.11)	.022 (.22)	-.221 (1.49)	.006
6	.007 (2.32)	.010 (.10)	-.119 (.78)	-.02
7	.009 (3.14)	-.140 (1.41)	.057 (.38)	.001
8	.009 (3.06)	-.145 (1.46)	.024 (.16)	.01

[*]$IP_{t+j} = b_1 + b_2 LI_t + R_t^{-1} + e_t$. IP_{t+j} denotes the quarterly growth rate in industrial production in quarter $t+j$, LI_t denotes the true growth rate of the leading indicators in quarter t, and R_t^{-1} denotes the cumulative revision (minus the first quarterly revision) of the leading indicators in quarter t. t-statistics are reported inside the parentheses.

Table 2

THE PERSISTENT IMPACT OF THE CUMULATIVE REVISION (MINUS THE FIRST

QUARTERLY REVISION) OF THE LEADING INDICATORS[*]

j	b_1	b_2	b_3	Adjusted R^2
1	.004 (1.33)	.198 (2.06)	-.230 (1.57)	.04
2	.008 (1.58)	.326 (2.01)	-.628 (2.53)	.07
3	.014 (2.12)	.347 (1.61)	-.849 (2.57)	.06
4	.020 (2.55)	.361 (1.38)	-.976 (2.43)	.05
5	.030 (3.18)	.210 (.68)	-.915 (1.96)	.03
6	.038 (3.72)	.067 (.20)	-.946 (1.84)	.03
7	.046 (4.15)	.004 (.01)	-1.103 (2.02)	.04
8	.051 (4.54)	.018 (.05)	-1.363 (2.44)	.07
9	.059 (5.10)	-.033 (.09)	-1.401 (2.46)	.08
10	.066 (5.63)	-.039 (.10)	-1.381 (2.40)	.08
11	.074 (6.19)	-.126 (.33)	-1.342 (2.31)	.08
12	.081 (6.75)	-.155 (.41)	-1.431 (2.48)	.10
13	.089 (7.44)	-.268 (.72)	-1.434 (2.52)	.12
14	.097 (8.27)	-.429 (1.17)	-1.325 (2.39)	.14
15	.103 (9.01)	-.429 (1.21)	-1.327 (2.48)	.16
16	.107 (9.68)	-.276 (.81)	-1.461 (2.84)	.17
17	.111 (10.48)	-.159 (.49)	-1.528 (3.11)	.18
18	.117 (11.38)	-.129 (.41)	-1.525 (3.23)	.19
19	.121 (12.11)	-.010 (.03)	-1.555 (3.38)	.18
20	.130 (12.55)	-.102 (.31)	-1.133 (2.37)	.10
21	.136 (13.08)	-.111 (.34)	-.950 (1.99)	.07

22	.142	-.138	-.916	.07
	(13.99)	(.43)	(1.95)	
23	.151	-.276	-.746	.08
	(15.82)	(.91)	(1.69)	
24	.159	-.335	-.660	.10
	(17.77)	(1.20)	(1.62)	
25	.164	-.215	-.771	.11
	(19.45)	(.82)	(2.03)	
26	.171	-.175	-.653	.08
	(20.37)	(.66)	(1.75)	
27	.178	-.121	-.554	.05
	(21.07)	(.46)	(1.49)	
28	.187	-.098	-.354	-.004
	(21.29)	(.36)	(.93)	
29	.195	-.015	-.205	-.04
	(20.90)	(.05)	(.51)	
30	.203	.025	-.028	-.05
	(20.21)	(.08)	(.06)	

*$\Delta IP_{t+2+j} = b_1 + b_2 LI_t + b_3 R_t^{-1} + e_t$. ΔIP_{t+2+j} denotes the cumulative growth in industrial production from the beginning of the third quarter following the initial announcement to the end of the $(2+j)$th quarter, LI_t denotes the true growth rate of the leading indicators in quarter t, and R_t^{-1} denotes the cumulative revision (minus the first quarterly revision) of the leading indicators in quarter t. t-statistics are reported inside the parentheses.