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INCREASING RETURNS, DURABLES AND ECONOMIC FLUCTUATIONS

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ABSTRACT

We describe an economy where a durable good is produced with an increasing returns to scale technology. Equilibria in this economy take the form of business cycles in which consumption fluctuates too much and is too low on average. A 2-sector version of this economy with imperfect credit and immobile labor also exhibits aggregate business cycles, in which outputs and labor inputs in different sectors move together. The model is consistent with a broad range of evidence on economic fluctuations.

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INTRODUCTION

In a market-clearing view of the business cycle, the economy goes through periods of high output and low leisure, and also through periods of low output and high leisure. In the middle of a boom, when the stock of durables is relatively high, the value of these durables in terms of leisure must be low, and therefore productivity and wages must be high to induce people to work. In contrast, in the middle of a recession, productivity must be low and costs high to induce the economy to rest.

One approach to such procyclical behavior of productivity is real business cycle theory (Kydland and Prescott 1982, Long and Plosser 1983) which relies on shifts of the production function. An alternative approach to productivity changes over time is increasing returns. There procyclical productivity results from largely endogenous movements along a downward sloping supply curve rather than from exogenous shifts of a conventional upward sloping supply curve. In this paper, we present a business cycle theory in which booms are associated with high productivity and real wages as a result of increasing returns, while recessions are associated with low productivity and real wages.

Several recent studies have found evidence in favor of increasing returns to scale. Hall (1986, 1988a,b) has presented evidence that several important manufacturing industries operate subject to decreasing average costs. Hall's results have been extended by Shapiro (1987) and Domowitz, Hubbard and Peterson (1988). Ramey (1988) presents evidence of decreasing marginal cost in the US automobile industry and surveys several studies with similar findings for other industries. In this paper, we adopt the simplest version of the decreasing industry marginal cost assumption, namely Marshallian externalities. We use this assumption because it allows us to combine price taking and increasing returns; we also discuss, but do not model, several more realistic market structures with increasing returns.

The paper is divided into two parts. The first part studies fluctuations in a single durable goods industry subject to a Marshallian externality. With a Marshallian externality, productivity is high at high industry output and low at low industry output, and no individual firm can by itself energize the industry and move it to high output and low costs. Because the good is durable, short run demand for it is extremely elastic, since consumers can easily substitute purchases over time. This combination of downward-sloping supply and flat short-run demand leads to a short run instability in the system. It is efficient for this industry to produce at capacity some of the time and to rest other times, rather than to always produce at a constant output level.

But efficient output fluctuations are not the likely equilibrium outcome when coordinated effort by many firms in the industry is required to change the industry output. There also are a variety of cyclical sunspot equilibria, in which consumption fluctuates excessively and output stays low longer than is efficient, because the industry cannot coordinate the end of the slump. Coordination failures convert the natural short run instability arising from the production of durables with increasing returns into inefficient and excessively long recessions.

Interestingly, however, recessions cannot last forever. As a recession continues, the stock of durables depreciates, and eventually people become willing to work for goods at such low wages that the economy naturally comes out of the recession. Similarly, the boom must end when people accumulate so many durables that they choose to rest despite high productivity. In this economy, although output is unstable in the short run, it is stable in the long run in the sense that neither booms nor recessions can last forever. The model's dynamics are determined by real factors as well as by sunspots.

The second part of the paper asks how sectoral volatility translates into volatility of aggregate output. Even with volatile sectoral output, fluctuations in aggregate production are not automatic, since various sectors can fluctuate out of step, leading to smooth aggregate output. We explore the implications for aggregate volatility of two assumptions: immobile labor and costly credit. The assumption of immobile labor means that workers are sufficiently specialized that they cannot move into whatever sector is productive at the moment. If workers are completely versatile, they can always work in whatever sector is productive to produce the good for their own consumption. In this case, workers do not really need to trade, and each sector can fluctuate at its own pace, without any interaction with other sectors. Smooth aggregate output is a likely equilibrium outcome. If, in contrast, labor is specialized and immobile, people need to trade to take advantage of increasing returns in other sectors. When a particular sector is operating at a high productivity because of increasing returns, workers in other sectors must either borrow or produce their own output in order to obtain the cheap goods of the currently productive sector. When borrowing is costly, it is easier for them to work in their own sector, which of course will lead to different sectors operating in step. This synchronization of cycles across sectors manifests itself in aggregate fluctuations.

As do real business cycles models, our model predicts procyclical productivity and real wages and a greater variance of production than of inventories[1]. In contrast to standard real business cycle models, however, our model predicts that productivity will increase even in response to pure demand shocks, as the economy takes advantage of increasing returns. Hall (1988a,b) presents some evidence that the Solow residual is in fact positively correlated with proxies for demand shocks. In the same vein, Mankiw (1987) mentions large productivity increases during WWII, when the government purchased a lot of durables. Unless the production function shifted, say due to increased effort, this result also supports increasing returns rather than real business cycle theories.

Our increasing returns model is part of a growing literature on the subject. Diamond (1982), Weitzman (1982), Shleifer (1986), Blanchard and Kiyotaki (1987), Diamond and Fudenberg (1988), Howitt and McAfee (1988), Cooper and John (1988), Cooper and

[1] Ramey (1988) explains the inventory puzzle using increasing returns while Eichenbaum (1988) relies on cost shocks.

Haltiwanger (1988), Kiyotaki (1988), and Hammour (1988), all present models where diffuse externalities play an important role in generating multiple equilibria and in some cases fluctuations. The innovations in our paper are twofold. First, we stress that the combination of increasing returns and durable goods leads very naturally to a plausible and easily interpretable form of short-run instability.[2] Second, we show that immobile labor and imperfect credit lead to a realistic theory of comovement of labor inputs and of outputs between different sectors of the economy. Both of these results help increasing returns models fit the stylized facts about business cycles.

PART 1: THE 1-SECTOR MODEL

In this section, we present a 1-sector general equilibrium model of an economy with industry-wide increasing returns in production or sales of a durable good. We first present a model of a representative consumer and derive his demand for durables and labor supply. We then present the industry supply curve under the assumption of increasing returns. In this economy, stationary equilibria exhibit production bunching, and equilibria without production bunching are unstable. Moreover, all cyclical equilibria but one are inefficient in the sense that recessions last too long, and the period of the cycle is too low.

Demand

We consider the representative consumer, with preferences given by:

$$(1) \qquad \int_0^\infty e^{-rt} \left\{ u(S(t)) - L(t) \right\} dt \, ,$$

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[2]Cooper and Haltiwanger's (1988) model is based on production runs of a storable good. Although their model is related to ours, they do not consider the short-run instability arising from the production of durable goods, or the coordination problems at either the industry or the economy level that we believe lie at the heart of fluctuations.

where S(t) is the stock of durables the consumer owns at time t, and L(t) is his labor supply. The assumption that labor is perfectly substitutible across periods simplifies our model, but also decreases the losses from output volatility, making it easier to generate fluctuations (Hall, 1988c). The evolution of the stock of durables is given by:

$$(2) \qquad \dot{S}(t) = X(t) - \delta S(t),$$

where X(t) is industry output at time t and δ is the depreciation rate.

The durability of the good leads to an important distinction between the long run and the short run demand curves. The long run demand curve for the good, D(X), is given by:

$$(3) \qquad u'(X/\delta) = (r+\delta)p,$$

where p is the price of the durable in utility units or leisure units. This demand curve is downward sloping. In the long run, at a lower price the consumer demands a higher constant stock of durables.

In the short run, in contrast, the stock of durables is essentially fixed, since the supply and depreciation over an instant are trivial relative to the stock. To calculate the short run demand curve, assume that consumers take all their future purchases as given. The instantaneous short-run demand curve is then horizontal, at the level of prices p(S(t)) given by the present value of future rental rates u'(S(τ)):

$$(4) \quad p(S(t)) = \int_t^{\infty} e^{-(r+\delta)\tau} u'(S(\tau))d\tau$$

At any price above p(S(t)), the consumer buys nothing at time t and consumes leisure instead; at any price below p(S(t)), his instantaneous demand is infinite. This demand curve relies on perfect intertemporal substitutibility of leisure.

Supply

We consider an industry subject to Marshallian external economies. There is a unit interval of competitive firms in this industry, each with a production function:

$$x = \ell \cdot f(X), \tag{5}$$

where x is firm's output, X is industry output, and ℓ is the firm's labor input. We assume that $f(0) > 0$, and $f' > 0$. This assumption makes the productivity of each firm an increasing function of industry output. Finally, each firm faces a capacity constraint: $\ell \leq \bar{\ell}$.

In a competitive equilibrium of this industry, it must be the case that:

$$x = X, \tag{6}$$

$$f(X) = w/p, \tag{7}$$

where w/p is the real wage. These conditions give us the industry supply curve, defined as the locus of price quantity pairs that can arise as an industry equilibrium. The supply curve subsumes the equilibrium wage, given by the current and future stocks of durables the consumer owns that firms today take as given. At this equilibrium wage, labor supply is perfectly elastic. Accordinglv, industry supply at the real wage w/p is given by:

$$X = f^{-1}(w/p), \tag{8}$$

provided that firms are not at the capacity constraint.

Let X_H solve

$$X_H = \bar{\ell} \cdot f(X_H), \tag{9}$$

so X_H is the industry's capacity output. The goods supply curve is then given in Figure 1: it is decreasing from $p = w/f(0)$ at zero output to $p = w/f(X_H)$ at capacity output, and then has a vertical spike at capacity output. This industry supply curve can be interpreted as

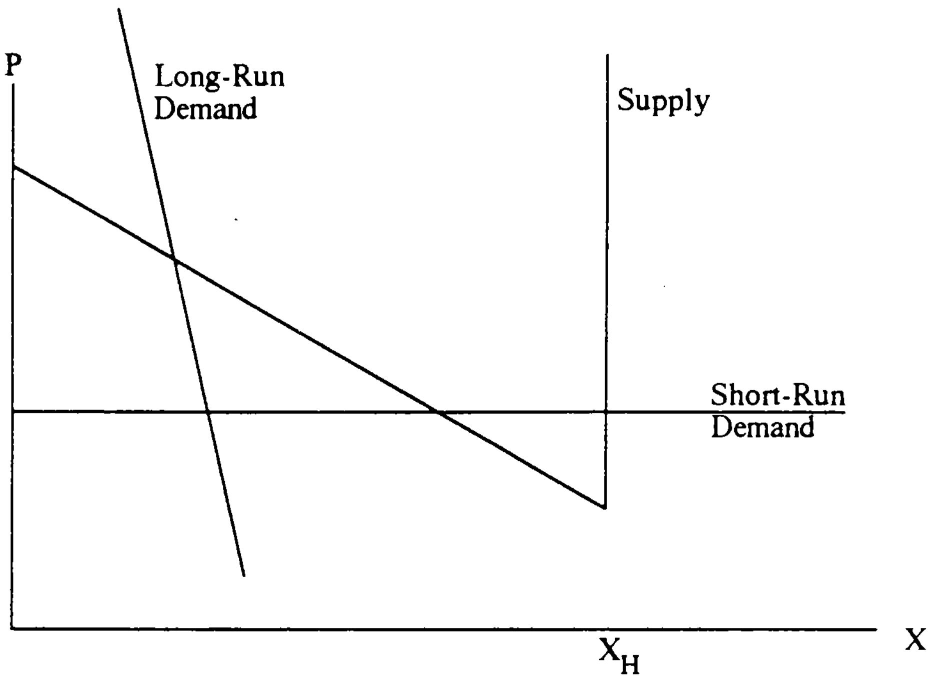

FIGURE 1: SUPPLY AND DEMAND

the social average cost curve, since:

$$(10) \qquad SAC = \frac{w\ell}{\ell f(X)} = \frac{pf(X)\ell}{\ell f(X)} = p.$$

The combination of this industry supply curve with horizontal short run demand is the reason for equilibrium fluctuations in this model.

The Marshallian externalities formulation enables us to combine increasing returns and price taking by firms (see also Romer 1986, Hammour 1988). A downward-sloping industry supply curve can also be obtained from more realistic, yet more complex formulations. For example, Diamond (1982) and Howitt and McAfee (1988) stress that high productivity at high output levels is due to scale economies in search and transacting. A good example of such an industry is housing. Consumers decide to search for houses when industry output is high, and no individual firm can have an effect on industry output. Some of the time, the housing market is liquid. It then pays people to go look for houses since variety is great and it will take less time and effort to find a house they like. In such times, it also pays firms to build houses, since expected holding costs are low. Other times, the housing market is illiquid. In those times, it does not pay consumers to search since it is costly to find a good match, and it does not pay firms to build since a house might be on the market for a long time. In this story, the effective marginal cost and the price fall with industry output, so the equilibrium industry supply curve slopes down.

Most industries do not have external economies of search as strong as those in the housing market. In more "organized" markets, a downward sloping industry supply curve may result from aggregating increasing returns in production or distribution that are largely internal to individual firms. The question is why such aggregation does not result in productivity rising to its maximum even at very low industry output levels, when one or a few firms operate close to capacity and capture the whole market. For increasing returns at the firm level to translate into a downward sloping industry supply curve, it must be the case that, even at low output levels, all firms divide the market rather than let a few meet the whole demand and take advantage of increasing returns.

We distinguish two cases of industry structure where individual firms have increasing returns production technologies and the supply curve of the industry slopes down. Take first the case of an oligopolistic industry of final good producers, each with an increasing returns technology. If, at low levels of industry demand, one producer cuts prices in an attempt to raise his market share, his price cuts are likely to be matched by other producers. The price cutter would then only capture roughly his original market share, and the price cut would not pay. This tendency of oligopoly to gravitate toward effective sharing of the market means that increasing returns cannot be fully exploited by having a small subset of producers take over the whole market and run at full steam. For firms to take advantage of increasing returns, total industry output must expand.

The second case of an industry with a downward sloping supply curve is an industry with multiple monopoly producers of different specialized intermediate inputs. Intermediate inputs are in turn used in different combinations to produce many competitively supplied final goods. Each intermediate producer's output is only a small fraction of the total cost of any final good, and these specialized inputs are not good substitutes. A consequence of the relative unimportance of any input for the output price, and of imperfect substitutibility between inputs, is that a price cut by the monopoly producer of any individual input leads to only a small increase in his sales. That is, the demand for any given specialized input is extremely inelastic. The producer cannot cut the price and hope to get a large enough increase in orders to enable him to fully realize increasing returns, since his output is almost completely dictated by the demand for the final good(s) and by prices charged by suppliers of complementary specialized inputs. Appendix A presents a "vertical linkages model" developed along these lines.

Equilibria

An equilibrium in this model is a path of output X(t), durable stock S(t), and price p(t), that makes all markets clear. Note that as long as (3) holds, the consumer is on his labor supply curve.

To make the model interesting, we assume that the long run demand curve D(X) cuts the downward sloping segment of the supply curve from above, as in Figure 1. If D(X) cuts a vertical segment of supply, the equilibrium is trivial: the sector always produces at a constant output level where supply intersects demand. Also, since X_H is given by physical capacity, we must explain why it pays to build so much capacity that it is not used all the time. The simplest reason is as follows. If capacity is sufficiently cheap relative to the average cost savings at higher capacity, it will pay a firm to build a lot of capacity and to operate it only some of the time to take advantage of extremely low average costs. Our assumption thus amounts to saying that building extra capacity on the margin is inexpensive relative to the average costs savings at higher capacity. Unpredictability of demand, growth of the economy and strategic considerations can also justify excess capacity, although these are probably less important than the simple reason we started with.

The combination of a horizontal short run demand curve and a steep long run demand curve gives our model short run instability and long run stability. If even the long run demand curve cut the downward sloping segment of the supply curve from below, then consumers' demand would be almost perfectly substitutable over time, and there would be enormous swings of production over the long run. By imposing a steep long run demand curve, we stipulate that consumers are willing to work for few goods when the stock is low, but when the stock is high are only willing to work in exchange for a lot of goods. This stipulation introduces limits on the extent of fluctuations of the stock of durables: neither booms nor recessions can last too long in our model.

We describe perfect foresight stationary (sunspot) equilibria in which the economy alternates between production level X_H for a time T_H and 0 for a time T_L. There are no intermediate output levels, and times spent at X_H and at 0 are constant forever. We call these equilibria cycles of period $T_H + T_L$. In these cycles, the stock of durables varies smoothly, but the output level jumps between its maximum and minimum levels.

A cycle in this model is completely defined by the time T_H spent at X_H and time T_L spent at 0. A cycle can also be described by the price p_L at which the economy switches from high to zero production, the capital stock S_H at that point, and the price p_H and the capital stock S_L at which the economy switches from zero to high production. Consider first the equations for p_L, p_H, S_H, and S_L for the cycle characterized by T_H and T_L. Capital stocks at turning points are given by:

$$S_H = \frac{X_H}{\delta} + e^{-\delta T_H}\left(S_L - \frac{X_H}{\delta}\right) \tag{11}$$

$$S_L = e^{-\delta T_L} \cdot S_H \tag{12}$$

The interpretation of (11) is that during the high production period, the durable stock moves toward X_H/δ, which it would achieve in the steady state if production were X_H forever. Of course, the durable stock never reaches this level and begins declining at S_H. Similarly, (12) says that during the low production period, the durable stock moves toward 0 but turns around when it reaches S_L.

For prices at turning points, the pricing equation (4) becomes:

$$p_L = \int_0^{T_L} e^{-(r+\delta)t} u' + e^{-(r+\delta)T_L} \cdot p_H \tag{13}$$

$$p_H = \int_0^{T_H} e^{-(r+\delta)t} \; u'(S(t)) + e^{-(r+\delta)T_H} \cdot p_L \, . \tag{14}$$

These equations are simply a consequence of pricing a durable at the present value of its future rental rates. The four equations (11), (12), (13), and (14) form a system that can by numerically solved for p_L, p_H, S_L, and S_H, for specific utility functions.

Several remarks can be made about these equilibria. First, even if we focus on stationary cyclical equilibria, the equilibrium set is 2-dimensional. Within some range, any amount of time spent at X_H and at 0 can support a cycle. These cycles are sunspot equilibria, in that a switch from high to low production level and back is coordinated by some device that aligns the expectations of all firms about the period of the cycle. Although, as we show below, some of these cycles might require less coordination than others, this paper does not solve the problem of picking out one of the many equilibria.

What happens during one of these cycles can be easily described (Figure 2). Over the period of high production, the durable stock and consumption are growing, whereas during the recession, the durable stock and consumption are falling. The rental rates on durables decline as the durable stock grows, and therefore rental rates are the lowest at the maximum stock of durables (the peak) and the highest at the minimum stock of durables (the trough). However, <u>the price</u> of durables is <u>not</u> the lowest at the peak and the highest at the trough. This price is just the discounted sum of future rental rates, and therefore at the peak, when all the future rental rates are higher than the current rate, the price cannot be at the bottom. In fact, this argument shows that the price of durables bottoms out sometime before the stock of durables peaks and begins to rise after that. Similarly, the price of durables reaches its top sometime before the stock reaches its bottom and begins to fall afterwards.

We can say a few more things about the range of possible prices p_H and p_L. In any business cycle, the lowest price of durables cannot fall below 1, since durables cannot be profitably produced at any price below 1, and therefore the price must rise as soon as it reaches 1. Similarly, the highest price, in any business cycle, cannot rise above α, since as

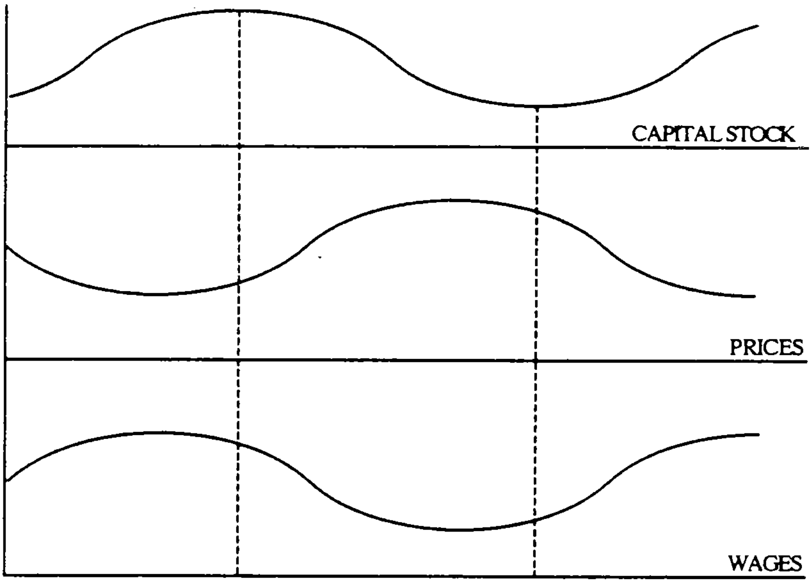

FIGURE 2: CYCLICAL VARIABLES

soon as it reaches α high production must begin and the price must fall. We show below that the cycle in which the lowest price of durables is 1 (achieved before the peak) and the highest price is α (achieved before the trough) is the natural "longest" cycle in this model.

We can also describe what happens in a business cycle in terms of real wages and profits, rather than in terms of prices. By real wages we mean wages relative to the price of the durable good, as opposed to, say, the rental rate. During the period of falling prices, real wages are rising, since workers are less eager to work when the durable stock is high and wages will be high in the near future. After the prices have reached their minimum and begin to rise, real wages begin to fall, even as the durable stock continues to expand. It's as if workers are giving wage concessions to firms because they recognize that a recession is coming soon and they will value durables a lot. But of course, in equilibrium, these concessions cannot be sufficient, and the recession arrives as expected. In a recession, when output is 0, the real wage is always $1/\alpha$ since returns to capacity are zero. Real wages are generally procyclical, except for the strange behavior of prices and wages at the end of the boom.[3]

Two types of cycles in this model deserve special attention. First, in chattering cycles, the durable stock is constant and the economy chatters between X_H and 0, so that $S_H = S_L$ and $p_H = p_L$. A chattering cycle is as the limit of a cycle where T_H/T_L is kept constant but the total period $T_H + T_L$ goes to zero. This model has a continuum of chattering equilibria corresponding to a range of durable stocks.

The model also has the longest cycle, in which the price of durables reaches the minimum of 1 during the boom and the maximum of α during the recession. In the longest cycle, the recession and the boom are as long as they can be in a cyclical equilibrium. If

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[3]The decline of real wages at the end of the boom is purely a consequence of perfect foresight. Real wages only fall at the end of the boom because people know for sure that a recession is imminent. Without the perfect foresight assumption, this result would not in general obtain.

the boom were to last any longer, the rental rates would get to be so low that at some point prior to the end of the boom the price of durables would have to fall below 1, which of course cannot be an equilibrium. Similarly, if the recession were to last any longer, at some point prior to its end the price of durables would have to rise above α, which of course could not be the case if production has to stay at 0. In the longest cycle, the economy has to get out of the boom because if people expect that it will not, the price of durables gets too low. Similarly, the economy has to get out of a slump because if people expect that it will not, the price of durables becomes too high to sustain a slump.

The longest cycle describes a natural form of stability in this economy that accords with our intuition: neither recessions nor booms can last forever. The longest cycle exists because the long run demand curve for goods is steeper than the supply curve, which means that after a period of high production people eventually require such high real wages that producers cannot break even paying them. Conversely, after a period of low production and the corresponding decline in the stock of durables, people are willing to give up leisure to produce goods even if their productivity is low. Without this assumption on the long run demand curve, long run stability no longer obtains. In the extreme case of horizontal long run demand, the economy is capable of operating at X_H forever or at 0 forever depending on the conjectures about what other producers will do. This case is closely related to the static multiple equilibrium results discussed by Murphy, Shleifer, and Vishny (1989).

This section has focused on equilibria in which only the maximum or the minimum output is produced at any point of time. Appendix B shows that equilibria with intermediate output levels are unstable in the sense that small output changes by individual firms can eliminate the equilibrium.

Welfare

In this section, we discuss the welfare properties of different cycles. We first show that, among the set of cyclical equilibria of a given period, cycles that have more time spent at the high output level relative to the time spent at low output lead to higher welfare. In particular, if we define a cycle by T_H/T_L (the ratio of times at the respective output levels) and by $T_H + T_L$ (the period), then moving to an equilibrium with a higher level of T_H/T_L holding $T_H + T_L$ constant raises welfare. Having thus established that there is too little capital in a cyclical equilibrium, we show that cycles last too long. Holding T_H/T_L constant, reducing $T_H + T_L$ raises a particular measure of welfare defined below. This result amounts to saying that consumption fluctuates excessively in a cycle. The two results imply that the first best is a chattering equilibrium for a particular T_H/T_L.

Relative Time Spent at the High Output Level

Consider any non-chattering equilibrium with production alternating between zero and X_H, and consider the welfare consequences of spending some infinitesimal additional period dt at X_H rather than 0. Recall that the representative consumer's utility is given by:

$$V(t) = \int_t^{\infty} e^{-r(\tau-t)}[u(S(\tau)) - L(\tau)]d\tau \tag{15}$$

The effect on V(t) of spending an extra dt at X_H rather than at 0, starting at time t, consists of a loss due to extra work and a gain due to extra consumption forever:

$$\begin{aligned} dV &= - X_H\, dt \int_t^{\infty} + e^{-r(\tau-t)} u'(S(\tau))\Delta S(\tau)d\tau \\ &= -X_H dt + \left\{ \int_t^{\infty} e^{-(r+\delta)(\tau-t)} u'(S(\tau))d\tau \right\} X_H \\ &= dt \left[-X_H + p(t)X_H \right] \end{aligned} \tag{16}$$

To get the second equality, we use the fact that $\Delta S(\tau) = e^{-\delta(\tau-t)}X_H dt$. To get the last equality, we take account of the fact that the discounted sum of future rental rates is equal to the equilibrium price. Since in any equilibrium the price p(t) must always be at least 1, it is clear that dV > 0. Spending more time at the high output level raises welfare.

This result implies that within the class of cyclical equilibria of a given period, raising the fraction of time spent at the high output level raises welfare. Raising T_H/T_L keeping $T_H + T_L$ constant amounts to slightly extending the boom and contracting the bust in every future cycle. This perturbation therefore amounts to making a welfare-improving change of the sort we discussed above in every cycle. Since each such change raises welfare, raising T_H/T_L strictly raises welfare. This result means that, in cyclical equilibria, booms are too short relative to recessions.

The Period of the Cycle

Establishing our second result--that shortening the period of the cycle $T_H + T_L$ raises welfare--runs into a problem. If we evaluate welfare at the start of a boom of a very long cycle, as long as the discount rate is high enough, utility is higher than at the beginning of the boom of a short period cycle. To evaluate the welfare of different cycles, we need a welfare index independent of the starting point. One index that does this is the expected utility in a cycle that starts at a random date t uniformly distributed between 0 and $T_H + T_L$. This expected utility is given by:

$$\text{(17)} \qquad W(t) = \int_0^{T_L+T_H} \left(\int_0^{\infty} e^{-r\tau} \left[u(S(\tau-t)) - L(\tau)\right] d\tau \right) \frac{dt}{T_L + T_H},$$

where t is the starting date and τ is the time index. [The starting point of the cycle is between $-(T_L + T_H)$ and 0]. Reversing the order of integration, we can rewrite W(t) as:

$$(18) \qquad W(t) = \int_0^{\infty} e^{-r\tau} \left\{ \int_0^{T_L+T_H} \left[u(S(\tau-t)) - L(\tau) \right] \frac{dt}{T_L+T_H} \right\} d\tau$$

Since the integral in the curly brackets is the undiscounted utility over one period of the cycle, its value does not depend on τ. Put differently, since cycles are repetitive, average undiscounted utility over any period of length $T_H + T_L$ is the same, regardless of where we start from. We can use this fact to integrate the last expression and write:

$$(19) \qquad W(t) = \frac{1}{r} \int_0^{T_L+T_H} \frac{[u(S(t)) - L(t)]dt}{T_L + T_H}$$

With this welfare index, we only need to calculate average undiscounted utility over one cycle.

For this welfare index, we can compare cycles of different periods holding the relative time in recession constant[4]. First, it is easy to show that, with a random starting date, average labor and the stock of durables over the cycle depend only on T_H/T_L and not on $T_H + T_L$. The reasoning is the same as that of average utility over a cycle with a random starting date. Second, since labor supply is perfectly intertemporally substitutable, the consumer does not care about the variation of leisure over time. Finally, we can show that the distribution of the durable stock S in a cycle of a higher period is a mean preserving spread of the distribution in a cycle of a lower period, holding T_H/T_L constant. This is because higher period cycles have the same capital stock trajectories as lower period cycles, except that they spend extra time at very high and very low capital stocks. Put together, these results imply that any risk averse consumer would pick a cycle of a lower period T_H +

[4]An earlier draft has presented the calculations. To save space, we omit them here.

T_L, holding T_H/T_L constant. This cycle would give him the same average consumption and leisure, but a lower variability of consumption.

We have shown that more time spent at high output is better, and that shorter cycles are better. The last result leads automatically to the conclusion that the first best output path consists of chattering between 0 and X_H, keeping the stock of durables and therefore consumption constant. In particular, the sector chatters between X_H and zero with the fraction of time spent at X_H equal to $\delta S^*/X_H$, where S^* is the optimal stock of durables. It turns out that S^* is equal to the maximum stock of durables sustainable in a decentralized chattering equilibrium. In this chattering equilibrium the price of the durable is always equal to 1. Recall that the price of a durable can never fall below 1 in equilibrium. But when the price of a durable is equal to 1, the value of durables produced by spending an additional unit of time dt at X_H is exactly equal to the cost of the additional amount produced. That is, $pX_Hdt = X_Hdt$. This means that the chattering equilibrium with the stock of durables S^* is the first best.

Interpretation

The two central features of our model--sectoral increasing returns and durable goods--lead to the result that some sectoral output fluctuations are efficient.[5] This means that taking an economy's peak output level and claiming that this level represents potential output that could be sustained permanently is incorrect. The Delong and Summers (1988) idea that the costs of business cycles can be calculated by filling in the gaps between output peaks is invalid in the presence of durables and increasing returns.

Although some output fluctuations are desirable, fluctuations in the stock of durables and therefore in consumption are not. In our model, there are no adjustment costs and

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[5]Our model is not rich enough to ask whether the amplitude of output fluctuations is too high or too low, since in all the cases we examine equilibrium output is at one of two levels.

therefore plants can be turned on and off instantaneously to take advantage of increasing returns. As a result, all fluctuations in the stock of durables and in consumption can be avoided by chattering. In this case, cycles with any positive period are too long in that they lead to excessive fluctuations in the stock of durables, as opposed to output[6]. Reducing the period of the cycle is a clear direction for improving welfare.

The second inefficiency in this model is that the equilibrium stock of durables is, in general, too low. The reason for underproduction is the coordination problem, that leads to too high a fraction of time spent at the low output level. That is, even if firms in the industry want to raise output and charge a lower price that would still enable the industry to break even, coordination failures prevent this from happening. Recessions in equilibrium are too long relative to booms. Shortening the recessions, or prolonging the booms, has the effect of raising the durable stock and welfare.

PART 2: THE 2-SECTOR MODEL

The question addressed in this part of the paper is whether sectoral fluctuations like the ones described in part 1 lead to aggregate output fluctuations. Business cycles exhibit an extraordinary amount of comovement of outputs and labor inputs between different sectors, which must be explained.[7] That is, we need to show why different sectors will not simply fluctuate independently of each other or even systematically out of step. To this end, we use a simpler model of a sector han the one in part 1, but consider a 2-sector model, say with cars and houses. The model is specified so that it has two (satisfactory) equilibria: one where cars and houses are produced at a high level at the same time (the in-step equilibrium), and one where cars are hot when houses are not and vice versa (the out-

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[6]Even with adjustment costs, where the optimum is a finite period cycle, longer cycles are probably too long.

[7]Murphy, Shleifer, and Vishny (1989) document this comovement.

of-step equilibrium). The first equilibrium obviously corresponds to the case of aggregate fluctuations.

We show that aggregate fluctuations are the likely equilibrium outcome under two realistic assumptions: immobile (or specialized) labor and imperfect credit and storage arrangements. To see this, suppose that the car sector is operating at high productivity and hence the price of cars is low. If labor is completely mobile, than all workers come to work in the car sector at high productivity to produce cars for their own consumption, and the house sector may as well be resting. There would be no aggregate fluctuations. Even if the workers in the house sector are specialized and cannot work in the car sector, if they can buy cars when they are cheap on credit, they will do so without necessarily working harder in the house sector at the same time. If, however, labor is immobile and borrowing is costly, the only way for the workers in the house sector to get cheap cars is to build houses and exchange them for cars when cars are cheap. This force stimulates comovement of outputs and labor inputs across sectors and therefore aggregate fluctuations.

We begin with a layout of our simplified model with two sectors and immobile labor. We then describe the in-step and the out-of-step equilibria with perfect credit markets. We next present the case of no storage and costly credit, and show that the set of parameter values for which the out-of-step equilibrium exists is smaller than the set for which the in-step equilibrium exists. Finally, we review the assumption of immobile labor.

A Simple Model

We consider a model with 2 sectors, each producing a durable good. One sector is called red, the other is called green. Time is discrete, and each good depreciates to δ of its original quantity in the second period of its life, and to 0 after that. We assume throughout that this good cannot be stored[8]. The cost schedule for producing each good is the same as in part 1. We take $X_H = 1$, the average cost equal to $\alpha > 1$ at 0 quantity and 1 at unit quantity. Instead of assuming that X_H is capacity, it is simpler to assume that X_H is the maximum labor supply beyond which the disutility of work is infinite. Importantly, we assume that labor is completely specialized and immobile between sectors, with red goods produced by red workers and green goods by green workers.

We assume that used goods markets do not exist. A new good must either be exchanged for another good when it is produced, or (if we allow credit) sold on credit when it is produced. The assumption of defective or non-existent secondary markets is particularly appropriate for durables, where there is often considerable asset specificity and adverse selection associated with unobservable depreciation in use.

The utility function of each worker--green or red--is given by:

$$(20) \qquad \sum_{t=0}^{\infty} \beta^t \left[u(S_G(t)) + u(S_R(t)) - \Psi(L(t)) \right] ,$$

where $S_G(t)$ is the stock of green goods at time t, $S_R(t)$ is the stock of red goods at t, and $\Psi(L(t)) = L(t)$ for $L(t) \leq 1$, and infinite for $L(t) > 1$. We assume that utility is separable both across time and between goods in the same period, and that the same utility is derived from the consumption of red and green goods. These assumptions ensure that demand complementarities do not drive the results.

Perfect Credit

The discrete time model we use to analyze the role of credit makes several assumptions to simplify the exposition of main points. First, we focus on a special case in which the

[8]We have analyzed the case of costly but not impossible storage, which leads to similar results as the case of costly credit. We do not deal with costly storage here.

relative valuation of goods and leisure is such that firms want to produce each good at the maximum output level every second period and rest completely inbetween. Put differently, there is only sufficient demand to produce the maximum output roughly half the time. Second, we assume that the first period depreciation ($1-\delta$) is small relative to the curvature of the utility function, so that firms do not want to spread their production more evenly between the two periods. These assumptions enable us to focus on stationary equilibria in which each sector produces at X_H every second period, and rests inbetween. The question we address is whether the two sectors are producing at X_H at the same time (in-step) or in alternating periods (out-of-step).

In the in-step equilibrium, each sector produces X_H during the boom and rests during the recession. In the boom, each sector exchanges half of its output for half of the output of the other sector, so that consumption patterns of all workers are identical. In the boom, each worker consumes 1/2 units of each good, and in the recession, each worker consumes $\delta/2$ units of each good. The in-step equilibrium thus exhibits some fluctuations in aggregate consumption and large fluctuations in aggregate output.

Importantly, the exchange of goods between sectors in the in-step equilibrium does not require any credit since goods are traded for each other as soon as they are produced. The conditions for the in-step equilibrium are therefore independent of the quality of credit.

The conditions necessary for the existence of the in-step equilibrium are twofold. First, each worker should be willing to work in the boom and buy goods with the proceeds. Since we adopt the labor supply interpretation of the goods supply curve, the real wage of each worker in the boom is 1. His marginal disutility of labor in the boom is 1, and his marginal utility of consumption of either good is $u'(1/2) + \beta\delta u'(\delta/2)$. A worker is willing to give up leisure in exchange for goods in the boom if:

(C1) $$u'(1/2) + \beta\delta u'(\delta/2) \geq 1.$$

The second condition is that, in the recession, workers do not want to give up leisure at the real wage of $1/\alpha$ to buy more of either good:

(C2) $$u'(\delta/2) + \beta\delta u'(1/2) \leq \alpha.$$

Conditions (C1) and (C2) are necessary and sufficient for the aggregate business cycle to exist. Because goods are swapped as soon as they are produced, this cycle requires no credit: such economizing on credit is the critical feature of aggregate cycles. Our results on out-of-step equilibria will take the form of showing that the necessary conditions for the existence of the out-of-step equilibrium are more stringent than (C1) and (C2). These results would then imply that, for some parameter values, the in-step equilibrium, which exhibits aggregate fluctuations, is the only equilibrium outcome.

In the out-of-step equilibrium, red goods are produced at X_H in odd (red) periods, and green goods are produced at X_H in even (green) periods. We focus on symmetric equilibria, in which the amount of goods that the green sector lends to the red sector in the green period is the same as the amount of goods the red sector returns in the red period. This assumption ignores the possibility that one sector might have started the lending, and hence in equilibrium gets more goods than it gives. All our credit arguments generalize to these asymmetric situations.

In a symmetric equilibrium with perfect credit, the producing sector gives half of its output to the resting sector, and gets half of that sector's output next period. Both red and green workers consume 1/2 units of the red good and $\delta/2$ units of the green good in red periods, and $\delta/2$ units of the red good and 1/2 units of the green good in green periods. Because of depreciation each good is consumed more in the period that it is produced than in the neighboring period. In this out-of-step equilibrium, both aggregate consumption and aggregate production are constant over time, although, just as in the in-step equilibrium, each type of labor is employed only half the time.

The set of necessary and sufficient conditions for the existence of the out-of-step equilibrium is the same in all credit examples we consider. The first column of table 1 presents these conditions, and columns 2 and 3 apply them to the cases of perfect and imperfect credit, respectively. Since we only consider symmetric equilibria in which the amount of goods transferred between sectors is the same in red and green periods, table 1 presents conditions that must hold in the red period. When these six conditions hold, both product markets and both labor markets clear, and all firms are in equilibrium.

To evaluate the difficulty of satisfying the necessary conditions for the existence of the out-of-step equilibrium, we present conditions 1-6 for the perfect credit case in the second column of table 1, and then compare them to conditions (C1) and (C2) for the in-step equilibrium. Denote by w_R the wage of red workers, by w_G the (shadow) wage of green workers, and by p_R and p_G the prices of red and green goods respectively, all in terms of some historical numeraire.

It is clear that conditions (3) and (1) together are equivalent to (C1) and (6) and (2) together imply (C2). Conditions (5) and (4) in this case do not impose any additional restrictions. These results show that the necessary and sufficient conditions for the existence of the in-step equilibrium and of the out-of-step equilibrium with perfect credit are the same. There are two reasons for this. First, we have assumed the separability of the utility function, so that it does not matter to consumers what proportions they consume red and green goods in. Consuming a lot of both goods in booms and little of both goods in recessions is as good as consuming a lot of one and a little of the other in alternating periods. If goods were complements, the conditions for an aggregate cycle would be easier to meet, and if they were substitutes, the conditions for the out-of-step equilibrium would be easier to meet[9]. The separability assumption ensures that our preference structure does not create a bias in favor of either equilibrium.

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[9] A related point is stressed by Cooper and Haltiwanger (1988).

Table 1

Necessary and Sufficient Conditions for the Existence of the Out-of-Step Equilibrium (Red Period)

	The Conditions	Application to the Case of Perfect Credit	Application to the Case of Costly Credit
1.	Red firms break even paying the product wage of 1.	$w_R = p_R$	$w_R = p_R$
2.	Green firms are unable to break even paying the product wage of $1/\alpha$.	$p_G \le \alpha w_G$	$p_G \le \alpha w_G$
3.	Red workers want to work at the wage of 1 to buy red goods.	$\frac{u'(\frac{1}{2}) + \beta\delta u'(\frac{\delta}{2})}{p_R} \ge \frac{1}{w_R}$	$\frac{MU^R_{RR}}{p_R} \ge \frac{1}{w_R}$
4.	Green workers do not want to work at the wage of $1/\alpha$ to buy red goods.	$\frac{u'(\frac{1}{2}) + \beta\delta u'(\frac{\delta}{2})}{p_R} \le \frac{1}{w_G}$	$\frac{MU^R_{RG}}{p_R} \le \frac{1}{w_G}$
5.	Red workers would rather buy red goods than green goods.	$\frac{u'(\frac{\delta}{2}) + \beta\delta u'(\frac{1}{2})}{p_G} \le \frac{u'(\frac{1}{2}) + \beta\delta u'(\frac{\delta}{2})}{p_R}$	$\frac{MU^R_{GR}}{p_G} \le \frac{MR^R_{RR}}{p_R}$
6.	Green workers do not want to work at the wage of $1/\alpha$ to buy green goods.	$\frac{u'(\frac{\delta}{2}) + \beta\delta u'(1)}{p_G} \le \frac{1}{w_G}$	$\frac{MU^R_{GG}}{p_G} \le \frac{1}{w_G}$

The second reason for the equivalence of necessary and sufficient conditions for the two equilibria is our assumptions of perfectly elastic labor supply and of immobile labor. If we had assumed instead increasing disutility of work and mobile labor, the most natural (and most efficient) equilibrium would be an out-of-step equilibrium in which every worker smoothed his labor hours by working in the green sector when it is hot and switching to the red sector in the alternate periods. We discuss this case in more detail below.

Costly Credit

With costly credit, workers specialize in consuming the good that they produce, but not completely. There is trade, but workers exchange less than half of their sector's output. We model costly trade by assuming that from the point of view of individual workers, when they give up red goods today for green goods tomorrow, a fraction λ of these red goods is wasted in the transaction. We assume that this fractional cost works as a tax or a transaction cost, so that it is not wasted in the aggregate. Aggregate addition to the stock of durables still equals aggregate output, but workers correctly perceive that the terms of intertemporal trade are distorted.

The effects of such costly trade arrangements can be easily modeled. Denote by MU^{i}_{jk} the marginal utility to worker k of getting an extra unit of good j in period i, where all the indices are either green or red. With this notation, we have that MU^{R}_{RR} is the marginal utility of the red good to the red worker in the red period, and that MU^{G}_{GR} is the marginal utility of the green good to the red worker in the green period. In this case MU^{R}_{RR}/MU^{G}_{GR} is the marginal rate of substitution between the red good in the red period and the green good in the green period for a red worker. Similarly, MU^{R}_{RG}/MU^{G}_{GG} is the marginal rate of substitution between the red good in the red period and the green good in the green period for a green worker.

Our costly credit assumption amounts to:

$$(21)\qquad \frac{MU^{R}_{RR}}{MU^{G}_{GR}} = \lambda \frac{MU^{R}_{RG}}{MU^{G}_{GG}}$$

When $\lambda = 1$ and credit is costless, red and green workers trade (by using credit) until their marginal rates of substitution are the same. With $\lambda < 1$, such trade is costly. As a result, red workers specialize in the consumption of the red good so their marginal rate of substitution is low (they consume a lot of the red good in the red period relative to the green good in the green period), and green workers specialize in the consumption of the green good so their marginal rate of substitution is high. When λ is low enough, there will be no credit extended at all and no trade. We assume that in fact λ is close enough to 1 for this not to be the case.

We are interested in the necessary conditions for a symmetric out-of-step equilibrium, in which red workers give X units of the red good to the green workers in the red period, and get back X units of the green good next period. Using our earlier notation, this means:

$$(22)\qquad MU^{R}_{RR} = MU^{G}_{GG} = u'(1-X) + \beta\delta u'(\delta(1-X))$$

The combination of (21) and (22) yields the equilibrium condition for X:

$$(23)\qquad \frac{u'(1-X) + \beta\delta u'(\delta(1-X))}{u'(X) + \beta\delta u'(\delta X)} = \sqrt{\lambda} = \frac{MU^{R}_{RR}}{MU^{G}_{GR}} = \frac{MU^{G}_{GG}}{MU^{R}_{RG}}$$

We claim that the necessary conditions for this equilibrium to exist are more stringent than the conditions (C1) and (C2) for the in-step equilibrium. The six necessary conditions are in table 1, column 3. We can combine conditions (1) and (3) to get:

$$(24) \qquad 1 \le MU^R_{RR} = u'(1-X) + \beta\delta u'(\delta(1-X)).$$

Since X < 1/2, this condition is more stringent than (C1). Next, multiply (2) and (4) to get:

$$(25) \qquad \alpha \ge MU^R_{RG} \cdot \frac{p_G}{p_R}$$

which together with (5) implies:

$$(26) \qquad \alpha \ge MU^R_{RG} \cdot \frac{MU^R_{GR}}{MU^R_{RR}} = \frac{MU^G_{GR}}{MU^R_{RR}} \cdot MU^R_{GR} = \frac{1}{\sqrt{\lambda}} \cdot MU^R_{GR}$$

Substituting in for MU^R_{GR}, this expression can be rewritten as:

$$(27) \qquad \alpha\sqrt{\lambda} \ge MU^R_{GR} = u'(\delta X) + \beta\delta u'(X)$$

Since $\sqrt{\lambda} < 1$, and $X < 1/2$, we know that $u'(\delta X) + \beta\delta u'(X) > u'(\delta/2) + \beta\delta u'(1/2)$, and so the last condition is harder to meet than (C2).

The interpretation of this result is very simple. With costly credit, or in the extreme case with no credit, it is undesirable to be out of step with the other sector. When this cost is high enough, firms begin switching to producing in step with the other sector by themselves, even if this means operating at low productivity. With high enough credit costs, the out-of-step equilibrium cannot be sustained. We interpret these results to say that economizing on aggregate credit naturally leads to aggregate fluctuations.

Implications of the 2-Sector Model and Comparison to Mobile Labor

In the model we have described, aggregate fluctuations are not necessarily bad, since (with a random starting date) welfare in the in-step equilibrium is the same as that in the out-of-step equilibrium with perfect credit. This implies that welfare in the in-step equilibrium is even higher than that in any out-of-step equilibrium when credit and storage are costly. In this model, there is nothing wrong with aggregate fluctuations.

This result obtains because we have not built into the model any cost of fluctuations of aggregate resource utilization. In particular, labor supply is elastic and labor is not mobile between sectors, so that in the in-step equilibrium labor is used as efficiently as in the out-of-step equilibrium. This, of course, need not be generally true. For comparison, we present the case of perfectly mobile labor and upward sloping labor supply, which illustrates the simple point that aggregate fluctuations can be socially costly.

With perfectly mobile labor, we can consider the representative consumer with the utility function (20) except we assume that labor supply is upward sloping: $\Psi' > 0$, $\Psi'' > 0$. All the assumptions about red and green goods remain the same. We assume that capacity X_H is 1 unit of labor in each sector. We also assume that the equilibrium is such that each sector chooses to operate at capacity when it is working.

Consider the in-step equilibrium first. In the work period, the worker supplies 1 unit of labor to each sector and consumes 1 unit of each good. In the rest period, he supplies no labor and consumes δ units of each good. The necessary and sufficient conditions for this equilibrium are:

(28) $$\Psi'(2) \leq u'(1) + \beta\delta u'(\delta)$$

(29) $$\alpha\Psi'(0) \geq u'(\delta) + \beta\delta u'(1)$$

The worker wants to work for the goods at high productivity in the work period, and does not want to work for the goods at low productivity in the rest period.

In the out-of-step equilibrium, the worker supplies 1 unit of labor to the red sector in the red period, and 1 unit to the green sector in the green period. He consumes 1 unit of the red good in the red period and δ units in the green period, and 1 unit of the green good in the green period and δ units in the red period. The necessary and sufficient conditions for this equilibrium are:

(30) $$\Psi'(1) \leq u'(1) + \beta\delta u'(\delta)$$

(31) $$\alpha\Psi'(1) \geq u'(\delta) + \beta\delta u'(1)$$

Our assumptions on Ψ imply that $\Psi'(2) > \Psi'(1) > \Psi'(0)$. This means that (28) is harder to satisfy than (30), and (29) is harder to satisfy than (31). In this case of aggregate decreasing returns due to labor supply, it is easier to have an out-of-step than an in-step equilibrium. Moreover, with a random starting date, the out-of-step equilibrium is clearly more efficient. It offers the worker an equally good consumption path as the in-step equilibrium, and lower variability of leisure. This case of upward sloping labor supply and perfectly mobile labor shows the benefits of asynchronization.

Unfortunately, this case is not the most interesting one, since perfectly mobile workers can completely avoid the use of credit and still work only in hot sectors. The more interesting case is one in which specialized workers produce a disproportionate amount of some goods, and therefore need credit or storage to trade them if output is asynchronized across sectors. Moreover, if workers do not specialize completely, there is a true social opportunity cost of having all sectors work hard at the same time. In this case, synchronization economizes on credit, but raises total production costs because labor is utilized disproportionately when it is expensive. Synchronized equilibria in this case would be particularly inefficient if the true social cost of credit is significantly lower than the private cost, as in many adverse selection models, and if labor is priced competitively. However, excessive synchronization can probably be an equilibrium outcome even without this deviation between the private and the social cost of credit. Inefficient outcomes might arise because of coordination problems similar to those in the 1-sector model, and they will manifest themselves in excessive fluctuations of consumption and of labor hours.

Interpretation of the 2-sector model

The model in this section generates comovement of both outputs and labor inputs from two essential assumptions: immobile labor and imperfect credit. The first assumption assures that individuals need to trade to take advantage of the opportunities to buy cheap goods. The second assumption assures that to exchange goods, people in different sectors must work at the same time. Under the assumptions of immobile labor and imperfect credit, the current level of aggregate income and demand is relevant for production decisions in different sectors of the economy. We can therefore interpret the model as showing that every sector wants to produce when aggregate demand is high, which is when other sectors are producing. The model in this section demonstrates very starkly that the need for trade is the essence of aggregate demand, and that immobile labor and imperfect credit are the two key assumptions that generate large aggregate demand effects.

The assumption of immobile labor has been used in the earlier literature on coordination problems to generate multiple equilibria, although the results have not been interpreted in terms of comovement (see Diamond 1982, Cooper and John 1986). In Murphy, Shleifer, and Vishny (1989), we show that immobile labor and imperfect credit generate comovement of outputs and labor inputs in a real business cycle model, as well as in a model with increasing returns. The reason of course is the same as here: immobile labor generates the need to trade, which leads to comovement of labor inputs no matter what the force driving productivity changes is.

The assumption of imperfect credit has also been used extensively in earlier work on fluctuations, although its usual role is different. Bernanke and Gertler (1989) and Greenwald and Stiglitz (1988) present models in which imperfect credit makes the firm's current cash flow relevant for its investment. In these models, recessions reduce the firm's cash, therefore its investment, and so have the tendency to persist. In our model, in contrast, the role of imperfect credit is to synchronize production between sectors, rather than to affect production within a sector. Put differently, imperfect credit here causes the effect of a shock to spread across sectors rather than to persist over time.

CONCLUSION

This paper has examined a number of implications for economic fluctuations of the production of durable goods with industry-wide increasing returns technologies. Our main conclusions can be easily summarized.

First, because short run demand for durable goods is very elastic and short run supply curve slopes down with increasing returns, output in the short run will be variable. Even with small cost advantages of producing large quantities, there can be substantial output variation over time. But the relative steepness of the long-run demand for durables naturally limits the length of booms and slumps. This means that, although there are a large number of possible cycles in our model, there is a well-defined longest cycle, in which saturation with goods relative to leisure brings about a slump, and the desire for goods relative to leisure brings about a recovery.

Second, a cycle in a durable goods industry can lead to excessive fluctuations in consumption of its output when coordination between firms is required to change industry sales. Poorly coordinated firms can get stuck at low output for much longer than is efficient. In such industry cycles, consumption fluctuates too much, but also average output is in general too low.

Finally, trade between different sectors with highly volatile production requires either the use of storage or credit, or else synchronization of production between these sectors, so that they can swap outputs when they produce them. When credit and storage are costly, the latter solution comes into use, leading to large fluctuations in aggregate output and employment. Although we do not show this explicitly, such cycles can last inefficiently long, for much the same reason as in part 1 of the paper. When labor is averse to large fluctuations in work hours, these aggregate fluctuations can be especially inefficient.

We conclude this paper by stressing that ours is a particular application of increasing returns to economic fluctuations, based on the procyclical fluctuations in productivity when the marginal cost curve is declining.[10] Such fluctuations in productivity make our model in many ways similar to real business cycle models of Kydland and Prescott (1982) and Long and Plosser (1983). An alternative approach to increasing returns is decreasing average costs, for which Hall (1988a,b) provides the evidence. Since decreasing average costs do not necessarily imply procyclical productivity, theories of fluctuations based on decreasing average costs need to come up with an alternative explanation to procyclical real wages and labor supply. One approach is countercyclical markups, but there may be others. In this area in particular, a great deal of work remains to be done.

[10]The appendix contains a vertical linkages story in which countercyclical markups are derived based on average variable cost pricing in the presence of potential competition.

Appendix A: The Vertical Linkages Model of Industry Supply

In this subsection, we present a simple model of an industry with a downward-sloping equilibrium supply curve. In this industry, inputs are specialized and complementary, so that the output of a particular input sector is determined by the output of the downstream industry, and cannot be profitably changed through unilateral action.

Assume that the durable good x is produced competitively with k intermediate non-durable inputs z_i, where k is a large number. Each input z_i is in turn produced from labor by a monopolist in its own sector. The cost function is the same for each z_i. The average variable cost curve of each z_i is declining until a fixed (sectoral) capacity is reached, as in Figure 1. That is, the average variable cost declines until some capacity z_{Hi} is reached and is vertical after that. Finally, assume that the monopolist in each sector i faces potential competition for "production runs," so the price q_i he charges is equal to his average variable cost. All we really need to assume is that the price falls with output, so a fixed markup over average variable cost would work as well. The question is: can an industry equilibrium be sustained in this model in which each intermediate input sector produces a low output and charges a high price (relative to wages), without having an incentive to cut prices in hopes of raising output and cutting average costs?

Let the cost function for the durable x be:

$$c(x) = g(x) \cdot q_1^{1/k}\, q_2^{1/k} \ldots q_k^{1/k}, \tag{A.1}$$

where $q_1, q_2, \ldots, q_k$ are intermediate input prices, k is large, and g(x) satisfies $g(0) = 0$, $g' > 0$, $g'' > 0$. This cost function corresponds to the production function

$$x = g^{-1}(z_1^{1/k} \cdot z_2^{1/k} \ldots \cdot z_k^{1/k}) \tag{A.2}$$

where $z_1, z_2, \ldots, z_k$ are the inputs.

This cost structure leads to the following demand curve for an intermediate input i, calculated by solving for the optimal output and then applying Shepard's lemma:

(A.3) $$z_i(p,q) = g((g')^{-1}\left(\frac{p}{q_1^{1/k}\cdots q_k^{1/k}}\right)\cdot\frac{1}{k}\cdot q_1^{1/k}\cdots q_i^{1/k-1}\cdots q_k^{1/k}$$

For a large k, the elasticity of this demand curve is close to -1. This means that when a monopolist in any intermediate input sector cuts his price, without comparable price cuts in other input sectors, his total costs rise but revenue does not. It does not, therefore, pay any input sector to cut its price, unless such a cut is coordinated among several or all of them. Prices can stay high and output low until the final goods sector raises its demand, in which case all input prices fall at the same time, as does the price of x.

Having shown that high prices of inputs and therefore of the durable can be sustained, we have to find the assumptions on g(x) that give us a V-shaped supply curve for x. Since the market for x is competitive, price is equal to marginal cost, which in the case of identical cost curves for all inputs is given by:

(A.4) $$MC(x) = g'(x)\cdot q(g(x)),$$

where $z = g(x)$ is the equilibrium quantity of each intermediate input and $q(g(x))$ is its equilibrium price. The condition on g that makes the supply curve of x V-shaped (with minimum output at 0) is:

(A.5) $$g''\cdot q + (g')^2\cdot q'(g(x)) < 0.$$

In this model, it does not pay the monopolist in any intermediate input sector to cut his price without other input sectors doing likewise. The reason is that each input is a small part of the total costs in the final goods sector, and therefore cutting the price of an intermediate input leads to only a small increase in its sales relative to the increase in costs. In other words, cutting the price of one input does not by itself lead either to much substitution into that input or to much increase in final output to sufficiently raise the demand for the input. If, in contrast, intermediate input sectors could coordinate their production decisions and raise output and cut prices altogether, the demand for these inputs would rise significantly and the price cut in fact would pay. The essence of this vertical linkages story is the coordination problem between different input sectors, that prevents them from making price cuts jointly.

Appendix B: Equilibria With Intermediate Production Levels

In the text, we have focused on equilibria in which production levels are either 0 or X_H. In general, there might be other equilibria, where at some points of time production is at intermediate levels. One such equilibrium is the constant output equilibrium where production is always at a constant level defined by the intersection of the supply curve with the long run demand curve. Although equilibria with intermediate output levels meet our definition of equilibrium, they are not stable with respect to small perturbations of demand. This instability arises from the fact that the short run demand curve is horizontal and the supply curve slopes down. As a result, if the actual demand is only slightly higher than is anticipated by firms, the average cost and therefore the supply price fall, which leads to infinite excess demand.

To see this argument in more detail, suppose that at some time t the output is X_t, such that $0 < X_t < X_H$. Instantaneous production at time t does not significantly affect any future capital stocks, and we assume that consumers expect their future purchases to remain fixed. Since we are considering an equilibrium, the short run demand curve must be horizontal at the level p_t, such that X_t is the equilibrium supply at p_t at the downward sloping segment of the supply curve (Figure A.1). This equilibrium is unstable in the following sense. If, at time t, demand is for some unspecified reason slightly higher than

X_t, competition forces prices down below p_t, and then of course demand is infinite.[11] As a result, output is forced all the way up to X_H. In this sense, equilibria with intermediate output levels are unsatisfactory.

This point can be made in a different way. Suppose that instead of a continuous supply curve, output can only be produced at discrete levels. In this case, the equilibrium with output levels between 0 and X_H simply does not exist (Figure A.2). To see this, consider some time t where the equilibrium price is p_t. For firms to supply at this price, output must be at least $X^u(t)$, shown in Figure A.2. But that output cannot be an equilibrium, since firms actually want to raise output at that price until it reaches x_H. In short, we do not have an equilibrium. This of course contrasts with the standard case of an upward-sloping discrete supply curve, where the equilibrium exists.

[11] The competition is between home builders in the thick markets story and between potential suppliers in each input market in the vertical linkages story.

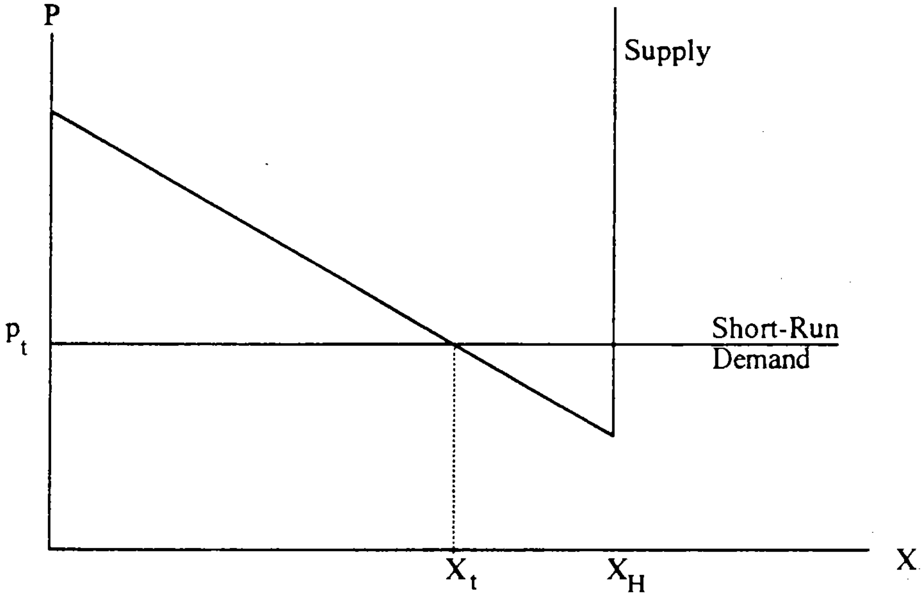
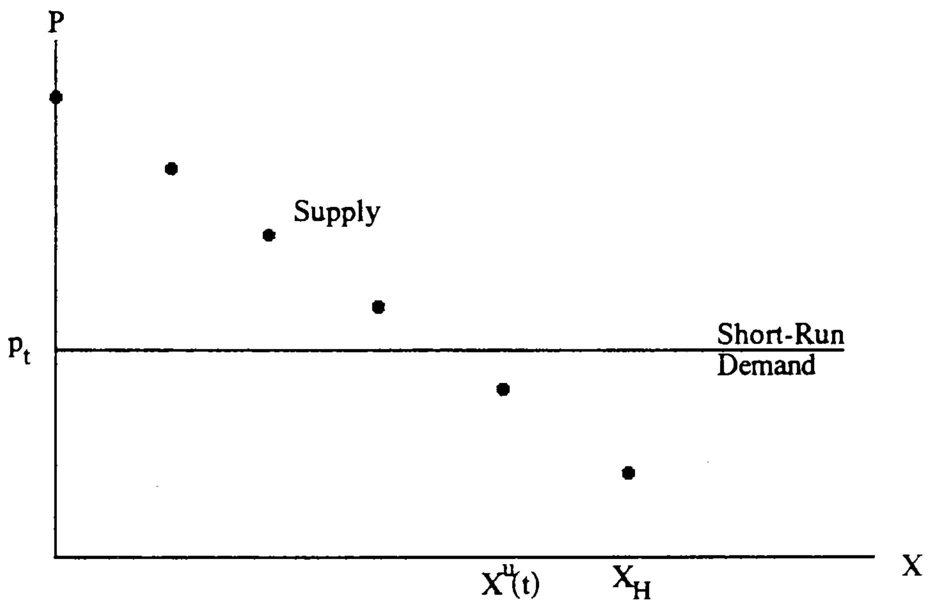

P
Supply
p_t
Short-Run
Demand
X_t
X_H
X

FIGURE A1


P
Supply
p_t
Short-Run
Demand
$X^u(t)$
X_H
X

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