# The Propagation of Demand Cycles when Purchases are Timed*

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**Abstract**

This paper demonstrates that, when sellers have market power and buyers time their purchases, predictable fluctuations in demand are fluctuations in the elasticity of demand. These fluctuations in the elasticity of demand alter the propagation of demand-driven cycles. The markup of price over marginal cost is shown to be low on the up-side of booms. When production exhibits increasing marginal costs, buyer intertemporal optimization limits price changes and produces countercyclical markups and greater persistence of transitory changes in demand. Empirical testing demonstrates that consumer goods for which timing is likely to be important do exhibit less real price response to demand-driven movements in sales.

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## 1. Introduction

Economic fluctuations, such as seasonal cycles or business cycles, result from the interaction of disturbances to an economic system and the endogenous responses of markets given technological constraints and agents' preferences. Many central models of business cycles explain only a small share of economic fluctuations as endogenous propagation and therefore interpret most cyclical variation as exogenous disturbances rather than as understood with the context of a model. This paper focusses on propagation in a particular market and shows that the timing of purchases naturally produces a structure of intertemporal linkages that generates both fluctuations in markups and slow adjustment of price and quantity in response to predictable changes in demand. Specifically, when sellers have market power and buyers time their purchases, predictable fluctuations in demand are necessarily fluctuations in the elasticity of demand. Given a predictable increase in demand, markups fall and sales are made sooner at the start of a boom. Further, with increasing marginal costs, as observed in more cyclical industries, markups are lowest at the peak of booms, and many sales are delayed so that the boom falls off slowly.

These results build on both the literature studying expenditures on durable goods, which emphasizes the propagation provided by agent heterogeneity and adjustment costs not relative price adjustment, and the literature studying countercyclical markups, which emphasizes the propagation provided by markups not agent heterogeneity and adjustment costs. Following the former literature, I assume that buyers must pay a fixed cost in order to transact. To avoid paying this fixed cost in all periods, agents buy or sell only infrequently, as in the canonical ($s$,$S$) model first used to analyze inventory dynamics (Arrow, Harris and Marschak (1951)). To date, the study of the timing of purchases in a market with such fixed costs of adjustment has been limited because of the complexity of the general problem. Specifically, equilibrium price and sales in depend on the amount of the good that each agent holds, making solution of the problem intractable. Thus most previous analyses of cyclical fluctuations in $(s,S)$ -type models assume a perfectly elastic supply curve so that the market clearing price is exogenous (e.g. Grossman and Laroque (1990), Caballero (1993), Eberly (1994), Adda and Cooper (2000a) and Carroll and Dunn (1997)).[1]

The present paper does not make this assumption and instead analyses a market in which buyers time purchases of a durable good and sellers have market power so that price changes endogenously as the distribution of agents across stocks of goods fluctuates. In order to make this problem tractable however the distribution of households is treated as exogenous, cyclical, and deterministic. While these assumptions are limiting, although in different ways from the rest of the literature, this model captures three features of price, quantity, and markup dynamics that are potentially important features of market fluctuations.

First, fluctuations in the distribution of buyers waiting to buy change the elasticity of demand. A firm considering decreasing its price weighs the lost profits on those consumers currently purchasing against the gain in sales made by encouraging more consumers to buy in the current period rather than later. The relative strength of the second effect at a given price is larger the faster the distribution of consumers is rising at that price, that is, the faster "potential" demand is increasing. Thus when demand starts to rise, prices fall and sales are made sooner than if prices had not moved. These price movements increase sales and decrease markups at the beginnings of booms, while decreasing sales and increasing markups at the starts of slumps.[2]

Second, since the good in question is durable, households have a greater

[1] Some sudies instead focus on special distributions (e.g. Caplin and Leahy (1997), Fisher and Hornstein (2001)) or steady-states (e.g. Stolyarov (1998)).

[2] This effect is related to the dynamics in Conlisk, Gerstner and Sobel (1984) and Domowitz, Hubbard and Petersen (1987) and the role of durability discussed in Carleton (1996). While, this effect is related to models of customer markets such as Phelps and Winter (1970) and Bils (1989) and the model of luxurious durable goods of Bils (1991), here variations in the willingness of the marginal customer to purchase appear naturally from the intertemporal subsitution of purchases.

ability to substitute intertemporally in response to predictable price movements than in a market in which household demand is separable across periods. The greater intertemporal substitution due to durability leads to greater quantity variation and less price variation. The ability of buyers to delay or accelerate their purchases smooths prices. On the other side of the market, sellers choose not to decrease markups much when demand is low because to do so would steal from their own future sales. With increasing marginal costs and market power, this real price stickiness generates a countercyclical markup.

Finally, durability and increasing marginal costs create a natural propagation mechanism. In a transitory boom, prices increase slightly and many buyers postpone purchases, increasing demand in later periods so that a shock in a single period is spread out over several periods.[3]

The model's implications are tested using panel data from the $NBER$ productivity database. Measures of the frequency at which households purchase good are obtained for a subset of four-digit manufacturing industries which correspond well to specific consumer goods. Goods purchased infrequently have small increases in price in response to demand-driven increases in sales. Analysis of whether these industries also have more countercyclical markups or markups which are lower when demand is increasing is inconclusive.

This paper is most closely related to two papers. First, Adda and Cooper (2000b) analyze the endogenous dynamics of sales in response to predictable price dynamics that do not depend on the distribution of households. Second, Caplin and Leahy (1999) study endogenous price dynamics in a similar system which is linearized and in which the density is always uniform local to the purchase point. In this alternative model, the second and third effects described subsequently can be studied, but the first is not present.

The balance of the paper is laid out as follows. The next section presents

[3]If marginal cost were constant, then transaction costs would still propagate demand over time, as pointed out in Caballero (1993).

a model in which buyers are price-takers and optimally time their purchases of a lumpy good. The complexity of the general problem and the key simplifying assumptions are discussed. Sections 3 and 4 characterize market dynamics when firms do not collude and when they do, respectively. Section 5 turns to industry-level data and tests the basic implications of the theory. The final section concludes and appendixes contain proofs and additional information about the data.

## 2. The Model

This section presents a model in which a population of buyers each choose when to upgrade a durable good. The complexity of the model motivates the addition of two simplifying assumptions that allow certain dynamics of the model to be characterized.

### 2.1. Consumers

The demand side of the market consists of a large number of potential buyers or consumers. Each consumer has some amount of a good which depreciates deterministically through time. Consumers are differentiated solely by their individual stocks in any period, denoted $k_{it}$, that, absent purchase, depreciate deterministically according to:[4]

$$k_{it} = (1 - \tilde{\delta})k_{it-1}. \tag{2.1}$$

The density of households per firm is denoted by $\tilde{f}_t(k)$. The evolution of the density of households is determined by endogenous factors, such as the price at which households choose to upgrade to a new good, and by exogenous factors, such as entry of new households into the market or government policy.

[4] I denote an individual consumer's or seller's stock, price, or sales using lower case letters, and market prices and quantities using capitals.

The market is assumed to be small, so that the fluctuations in prices in this market can reasonably be assumed not to affect any agent's marginal utility of wealth. Let the money-metric utility flow from the stock of the good be logarithmic and additively separable from other goods,

$$u_{it} = \frac{1}{\lambda} \ln(k_{it}), \tag{2.2}$$

where $\lambda$ is the marginal utility of wealth. As long as a consumer does not purchase a new good, its utility flow evolves according to:

$$u_{it+1} = u_{it} - \delta \tag{2.3}$$

where $\delta = -\frac{1}{\lambda} \ln(1 - \tilde{\delta}) \simeq \frac{\tilde{\delta}}{\lambda}$. The density of households per firm over utility flows is denoted $f_t(u)$.

Consumers are price takers and decide when to purchase a single new good. In every period, each consumer, $i$, observes the price of one randomly drawn seller, $j$, but does not automatically observe the price of any other seller. Let $V_t(u_{it}, p_{jt})$ denote the value of observing $p_{jt}$ and having old stock $u_{it}$ at time $t$. The value function is subscripted by $t$ to denote its dependence on the state of the system, to be specified shortly.

In each period, the consumer chooses among the following three options. First, the consumer can choose to do nothing, in which case it receives the benefits of its current stock, and, in the next period, faces the same decision with the price of a new randomly drawn seller. The value to this choice is: $u + \beta E_t[V_{t+1}(u - \delta, p_{kt+1})]$, $0 < \beta < 1$.

Second, the consumer can purchase a new good at the observed price. To focus on timing issues, consumers decide only <u>when</u> to buy, not <u>how much</u> to buy. To generate infrequent purchase, fixed costs of adjustment are assumed. Specifically, the costs to transact are extreme: a buyer who upgrades to a new good gets nothing for its old good. In this case the consumer pays $p_{jt}$ and receives the utility flow from a new good, $k^{new}$, and then faces the same decision next period with $\left(1-\tilde{\delta}\right)k^{new}$ in hand. Each consumer-$k^{new}$ match has an idiosyncratic match specific value, realized only after the good is purchased. Given sufficiently large support for this match-specific shock, the distribution of consumers over $k$ is continuous. Let $u^{\max} = E\left[\frac{1}{\lambda}\ln(k^{new})\right]$. The expected value of purchasing a new good is given by $u^{\max} - p_{jt} + \beta E_t[V_{t+1}(u^{\max} - \delta, p_{kt+1})$.

Third, the consumer can pay a search cost $c$, and observe the price of a new randomly drawn seller. It then faces the same decision again in the current period: purchase, wait, or continue searching.[5] The search cost gives producers some market power in the manner of Diamond (1971).

Prior to searching, consumers know the distribution of prices posted by sellers, and the payment of search costs yields only information about a specific seller's price. Thus, if a consumer ever prefers searching to delaying, it searches in the current period until it finds an acceptable price and purchases. Consequently, once any potential buyer chooses to search, the problem is a stationary search problem and consumers search across firms until they find a price below their reservation price. The value to searching is the maximum of the value of buying at the current price, or paying $c$ and going to a new seller and discovering its price:

$$V_t^s(p_{jt}) = Max\{u^{\max} - p_{jt} + \beta E_t[V_{t+1}(u^{\max} - \delta, p_{kt+1}), E_t[V_t^s(p_{kt})] - c\}. \quad (2.4)$$

The value of a consumer with a utility flow of $u$ who sees a price offer of $p_{jt}$ can now be written recursively as:

$$\begin{aligned} V_t(u, p_{jt}) &= Max\{u + \beta E_t[V_{t+1}(u - \delta, p_{kt+1})]\ , \qquad (2.5) \\ &\quad u^{\max} - p_{jt} + \beta E_t[V_{t+1}(u^{\max} - \delta, p_{kt+1})], E_t[V_t^s(p_{kt})] - c\} \end{aligned}$$

where $\beta$ is the consumer's discount factor. Equation (2.5) says that the value of having utility flow $u$ in period $t$, and seeing the price of one good, $p_{jt}$, is equal

[5] Each period thus consists of an infinite number of instants in which consumers can choose to search over prices/goods. If a buyer is intent on purchasing in a given period, it can visit as many sellers (and pay as much in search costs) as it wishes within a single period.

to the maximum of 1) the expected value of waiting, 2) the value of purchasing at the observed price, and 3) the value of deciding to purchase, but doing some searching over prices first. Since consumers always end search by purchasing, henceforth entering the search mode is called purchasing.

### 2.2. Sellers

Characterizations of equilibrium are presented when firms collude and when they do not. The collusive equilibrium is discussed in section 4.

There are a unit mass of identical sellers along the unit interval. Absent collusion, each seller posts a price in each period and sells to those consumers who arrive and have reservation prices above the seller's posted price. Attention is restricted to symmetric Nash equilibria. The search process gives each seller some market power. That there are an infinite number of sellers means that each one ignores the impact of its own price on the market price and its own future sales. Future sales are a common resource, overexploited from the perspective of a collusive equilibrium.

Sellers choose a price, $p_{jt}$, in each period to maximize static profits:

$$E_t\left[p_{jt}q_t(p_{jt},P_t)-c_1q_t(p_{jt},P_t)-\frac{1}{2}c_2q_t(p_{jt},P_t)^2\right] \tag{2.6}$$

where expectations are formed about the actions of other firms which determine the market price, $P_t$. The function $q_t(p,P)$ is the amount of sales that a seller charging $p$ makes in period $t$ when the market price is $P$. This function is determined by the density of potential consumers and their optimal strategies. $c_1$ and $c_2$ represent quadratic costs of production, both of which are weakly positive.[6]

[6] The problem could also contain fixed costs to entry and fixed costs in each period, both of which would determine market size and ensure that sellers not make net profits in excess of the usual rate of return. These costs are not relevant to the analysis at hand and are ignored.

### 2.3. The State Space

In the equilibrium of this model, households choose when to purchase based on the expected path of future prices which in turn is determined by the confluence of endogenous and exogenous factors that determine the density of households over their holdings of the good. The state space of the value function contains $f_t(u)$. Characterization of behavior in this general case has proven intractable, so that market dynamics have been studied only in special cases, such as when supply is perfectly elastic.

In order to approximate the equilibrium dynamics of this model when price is responsive to changes in demand, the next subsection presents two simplifying assumptions that, while not reducing the state-space of the problem, do allow one to characterize and simulate a class of non-steady state solutions.

### 2.4. Two Simplifying Assumptions

First, households that purchase a new good do not use the state of the distribution to forecast the price for the next time they wish to purchase.

**Assumption 1**

$$\begin{aligned} u^{\max} + \beta E_t[V_{t+1}(u^{\max} - \delta, p_{kt+1})] &= u^{\max} + \beta E[V_{t+1}(u^{\max} - \delta, p_{kt+1})] \\ &\equiv v \end{aligned}$$

Since the state of the system only matters to potential buyers when they actually buy, this condition is likely to be close to true if there is significant time between purchases. In this case, difference in the price that the household faces when it next purchases caused by delay in the present would be heavily discounted and have a small effect on today's decision. If there were idiosyncratic differences in depreciation rates, as in the real world but not the model, the assumption is also likely to provide a reasonable characterization since idiosyncratic risk makes the aggregate state less useful in forecasting the price dynamics at an uncertain date in the future. Caplin and Leahy (1999) prove that this assumption is in fact a feature of the general model as the length of time between purchases gets large enough.

Second, the density of households consists of an exogenous inflow of new households into the market. This density fluctuates, is deterministic, and has an endogenous lower endpoint determined by household and firm optimization as follows.

**Assumption 2** The density of households evolves according to:

$$f_t(u) = \begin{pmatrix} f_{t-1}(u+\delta t) + g_t(u) & u_t^+ \leq u \leq \bar{u} \\ 0 & \text{otherwise} \end{pmatrix} \tag{2.7}$$

where $f_t(u)$ and $g_t(u)$ are continuous, atomless, bounded above, and strictly positive over $[u_t^+, \bar{u}]$; $g_t(u)$ is deterministic and strictly positive only over $[\bar{u}-\delta, \bar{u}]$; and $u_t^+$ denotes the utility flow of the buyer with the least amount of the good in the market at the beginning of period $t$.

Fluctuations are driven by predictable, exogenous changes in the distribution of households waiting to purchase. These predictable fluctuations are meant to correspond to seasonal variations in demand, predictable changes in marginal utility of wealth as might occur at the end of a recession or following a monetary contraction, or the "echo effects" of previous technological boom or government policy that causes a large group of agents to have similar stocks.[7]

Three points about this assumption deserve note. First, while the evolution of the height of the density of households about to purchase is exogenous, the density is not because the evolution of $u_t^+$ is endogenous. Consumer and firm optimization determines $u_t^+$ as the height of the density fluctuates. Variation in $u_t^+$ delivers complex dynamics from simple exogenous fluctuations in distribution height. Second, assumption 2 eliminates the ability to study the response to shocks.

[7] Adda and Cooper (2000a) study an example of this last type of fluctuations, one driven by changes in government subsidies to the scrapping of old automobiles.

Finally, assumption 2 implies that a large group of purchases at time $t$ does not leading to a large demand at some future date when these same households prepare to purchase again. While this assumption formally eliminates these "echo effects" it allows the study of predictable movements in the number of households about to purchase, such as echo effects would generate. Perhaps the best example of such variation is seasonal fluctuations in demand.

### 2.5. Consumers and Firms Redux

Using assumption 1, the consumer value function simplifies to:

$$V_t(u, p_{jt}) = Max\{u + \beta E_t[V_{t+1}(u - \delta, p_{kt+1})],\ v - p_{jt}, E_t[V^s(p_{kt})] - c\} \quad (2.8)$$

The value function for the household remains a function of time– the buyer's optimal purchase date depends on the price path that it faces. The time-path of prices in turn depends on the true state of the system: everything needed to forecast the future evolution of the density of consumers over utility flows. However, for cyclic equilibria there are a finite number of such value functions so that the model is tractable to solve.

Using assumption 2, the firm's first order condition can be written as an inverse elasticity pricing rule:

$$\frac{p_{js} - c_1 - c_2 q_s(p_{js}, P_s)}{p_{js}} = \frac{1}{\epsilon_s^d(p_{js}, P_s)}, \quad (2.9)$$

where $\epsilon_s^d(p_{js}, P_s) \equiv -\frac{\partial q_s(p_{js}, P_s)}{\partial p_{js}} \frac{p_{js}}{q_s(p_{js}, P_s)}$, the elasticity of firm demand given the market price.

### 2.6. Market Equilibrium

This section solves for the consumer policy functions, $\{q_t(p, P)\}_{t=0}^{\infty}$, by means of a series of lemmas and defines the equilibrium of the model.

**Lemma 1.** *No search. In a symmetric equilibrium, no consumers search and*

$$V_t(u, p_{jt}) = Max\{u + \beta E_t[V_{t+1}(u - \delta, P_{t+1})]\ , v - p_{jt}\} \quad (2.10)$$

The proofs of all lemmas are contained in Appendix $A$. Since in every period all firms charge the same price, any search has a total expected gain of minus the search cost. Define $T_{tj}$ as the expected purchase date of consumer $j$ conditional on information available at time $t$.

**Lemma 2.** *Skimming property.* $u_{ti} > u_{tj}$ *implies* $T_{ti} \leq T_{tj}$.

This lemma follows from a revealed preference argument, which demonstrates that the value function (equation (2.8)) is weakly increasing in its first argument. Since prices are bounded below by $c_1$, the value function is bounded above for a positive depreciation rate and discount rate less than one.[8] Thus, provided the first term is always positive, a finite purchase time is optimal.

Given lemma 2, sales in any period can be calculated by finding the buyer who is indifferent between purchasing and waiting, and then summing over consumers with lower utility flows. Let $u_t^*$ be the utility flow of the buyer with the smallest stock of the good after sales have been made in period $t$. Then by equation (2.3)

$$u_{t+1}^{+} = u_t^* - \delta. \tag{2.11}$$

**Lemma 3.** $u_t^*$ *evolution. Provided that sellers sell to some consumers in every period,* $u_t^*$ *is defined by*

$$u_t^* = (1 - \beta)v + \beta E_t \left[P_{t+1}\right] - P_t \tag{2.12}$$

Equation (2.12) is derived from equation (2.10) by noting that the marginal consumers today will buy tomorrow, and, therefore, that their expected value to delaying is the expected utility of purchasing in the next period.

**Lemma 4.** *Positive sales. If* $q_0 > 0$, *and* $p_t \geq c_1$ $\forall t$, *then* $q_t > 0$ $\forall t$.

[8] Marginal costs are assumed to be weakly increasing so that prices are bounded below by marginal cost when producing the first increment of output. The facts that utility flow depreciates linearly and firms discount future profits exponentially are sufficient to generate bounded returns in this setup.

This lemma provides the conditions that insure that equation (2.12) holds with equality in all periods. Lemmas 3 and 4 together imply that equation (2.12) gives $u_t^*$ and (2.11) in turn gives $u_t^+$.

To derive $q_t(p_t, P_t)$, first note that if all sellers are charging $P_t$, then, for every seller the quantity of sales is the integral of the buyer density from $u_t^+$ to $u_t^*$:

$$Q_t(P_t) \equiv \int_{u_t^+}^{(1-\beta)v+\beta E_t[P_{t+1}]-P_t} f_t(u)du. \tag{2.13}$$

Now consider a seller who deviates from the market price. If the seller cuts price, then it sells to a larger share of the consumers who see its price in the current period. However, it gains no sales from other sellers since no consumer finds it worth searching across such a large number of sellers when it knows only one seller has cut its price. Thus for all price cuts:

$$q_{jt}(p_{jt}, P_t) \equiv \int_{u_t^+}^{(1-\beta)v+\beta E_t[P_{t+1}]-p_{jt}} f_t(u)du. \tag{2.14}$$

For price increases, the seller may lose some of its customers. However, as long as the price increase is smaller than $c$, no one leaves the seller to search, although some consumers may decide to delay purchase rather than buy or search. Thus, equation (2.14) determines demand for $p_{jt} \in [c_1, P_t{+}c)$; for higher prices, demand is zero. Note that $q_{jt}(P_t, P_t) = Q_t(P_t)$.

Given a set $\left(f_0(u),\ u_0^+,\ \{g_s(u)\}_{t=0}^{\infty}\right)$, an equilibrium is a series $\{P_s, u_s^+\}_{t=0}^{\infty}$ which satisfies the following.

1. Consumers optimally choose the timing of their purchases

$$u_{t+1}^+ = (1-\beta)v + \beta E_t\left[P_{t+1}\right] - P_t - \delta \tag{2.15}$$

2. The forcing term evolves according to equation (2.7).

3. Firms maximize profits

$$\frac{P_t - c_1 - c_2 \int_{u_t^+}^{(1-\beta)v+\beta E_t[P_{t+1}]-P_t} f_t(u)du}{P_t} = \frac{\int_{u_t^+}^{(1-\beta)v+\beta E_t[P_{t+1}]-P_t} f_t(u)du}{P_t f_t((1-\beta)v + \beta E_t\left[P_{t+1}\right] - P_t)} \tag{2.16}$$

4 Expectations of all firms' current and future behavior is correct: $E_{t-s}[P_t] = P_t$ for all $s \leq t$.

In equation (2.16), the integral terms are the market quantity sold in period $t$, and the right-hand-side is the inverse of the elasticity of demand. Note that, in choosing prices, firms take $u_t^+$, $P_t$, and $E_t[P_{t+1}]$ as given, and that the first-order condition is evaluated at the market price.

### 2.7. The Steady State

The steady state of the system is defined as those constant quantities and prices that solve conditions 1 through 4 when there are a constant, known, amount of households at each stock of durable goods. Let $\alpha$ be the height of this distribution of consumers over utility flows, i.e. $f_t(u) = \alpha \ \forall t, \forall u \geq u_t^+$.

**Lemma 5.** *Steady state equilibrium.* The steady state is uniquely determined by:

$$\begin{aligned} P_{ss} &= c_1 + c_2\alpha\delta + \delta \\ u_{ss}^+ &= (1-\beta)(v - P_{ss}) - \delta \\ Q_{ss} &= \alpha\delta. \end{aligned} \tag{2.17}$$

The steady state quantity sold depends solely on the number of consumers at each point in the density and the speed at which consumers' utility flows depreciate. Note that the equilibrium markup rises with the depreciation rate.

The next section analyzes the two main economic forces that are captured in the first order conditions above and that generate the dynamics of the system. Two dynamic simulations are presented and the importance of assumptions, particularly that of discrete time, are discussed.

# 3. Market Dynamics

The equilibrium dynamics arise from two features of the equilibrium conditions. First, in equation (2.16), the reduction in profits on inframarginal consumers for a small decreases in price, $Q_t(P_t)dP_t$, is exactly balanced by the increase in profits due to additional consumers who decide to buy at $t$, $[P_t - c_1 - c_2 Q_t(P_t)]\, f_t\,()\, dP_t$. Thus, there is a tendency for markups to be lower and for consumers to purchase sooner when the density of consumers is increasing rather than flat, that is, when marginal consumers become more important relative to inframarginal consumers. As shown subsequently in simulations, this effect causes quantity fluctuations to start earlier.

Second, the quantity of sales is determined relative to the expected market price in the next period. Sellers are unable to sell if today's price is set much above future prices. High prices in the present increase the share of inframarginal households in the future and keep prices high causing more delay of purchases. This effect tends to produce propagation. Consider the flat distribution $f\,() = \alpha$ and constant marginal cost, $c_2 = 0$. Figure 1 shows the phase diagram for this linear system, which is saddle path stable. In a market with a low $u_t^+$, $Q_t(P_t)$ is large given $P_{t+1}$, while the marginal sales are the same, $f\,() = \alpha$. But the future of these markets is also different. Since $P_t$ is high, $u_{t+1}^+$ is below steady-state, and by the same logic, $P_{t+1}$ will again be high.[9]

## 3.1. Demand Fluctuations with Constant Marginal Cost

For general sequences of $\{g_t(u)\}$ the solutions to the time-dependent difference equations (2.7), (2.15) and (2.16) involves the solution to a large (potentially infinite) number of equations. To preserve tractability while characterizing equilibrium dynamics, a solution to conditions $1-4$ is found for a density of utility flows over consumers, $f_t(u)$ (and therefore $g_t(u)$), that has infinitely repeating,

[9] The roots of the system are $\frac{1}{2}+\beta^{-1}\mp\sqrt{\frac{1}{4}+\beta^{-2}}$ which are two positive roots, one unstable, one stable.

deterministic cycles. That is, in solving the model, the distribution of households that the firms face is periodic. Given a choice of periodic distribution, the initial $u_t^+$ is chosen so that in equilibrium $u_t^+ = u_{t+\tau}^+$ where $\tau$ is the period of $f_t(u)$.[10]

Figures $2A$, $2B$, and $2C$ display the results of a typical simulation when firms have constant marginal costs and the density of consumers over stocks is taken to be a square wave.[11] The figures demonstrate the first feature of market dynamics described in the introduction and observed in the first-order conditions. Price (Figure $2A$) is set in part according to the change in the height of the density (Figure $2B$, dashed line). When a large number of consumers get near to buying, price declines and quantity sold is higher than if price did not respond. This effect causes the boom to begin earlier and reduces markups on the up-side of booms. This effect also drives down the price and quantity immediately before the boom in market demand, amplifying the lack of sales at the end of the period of low sales.

The second effect observed in the first-order conditions is also present: consumer optimization smooths price. Consumers know that the price will fall in period 2, so they substitute towards that period; sellers respond by cutting price in period 1. Low levels of the lowest utility flow at the start of the period occur when households are allowing their stocks to depreciate farther than usual before upgrading (Figure $2C$). These stocks are the lowest immediately before the lowest price periods and the highest immediately before the highest price periods.

The same factors amplify the end of the boom, as consumers substitute away from the high prices that occur as the decline in sales begins. Once the period of

[10] A similar method is used in Caballero and Hammour (1994) to study the adoption of new technology. I use a multiple shooting technique to find a cyclical series of prices and cutoff utility flows that satisfy the equilibrium conditions, taking the steady-state values as the starting points for this search process (see Judd (1998)).

[11] Due to the stylized nature of the model, the model is not calibrated beyond setting the parameters so price exceeds marginal cost by 15 to 20 percent in all of the simulations.

low sales arrives, the marginal consumer has a low stock of the old good, having just been waiting to purchase because of the high prices at the end of the boom. Price declines only slowly due to the presence of fewer inframarginal consumers at the start of the low-demand time.

These dynamics are consistent with pre-season sales on seasonal items, such as clothing. Seasonal variation in demand provides a predictable increase in the number of households seeking, for example, to purchase summer clothes at the start of the summer. Retailers respond by holding pre-season sales on summer clothes in the spring, cutting prices and markups and moving sales from the summer boom into the spring.

### 3.2. Demand Fluctuations with Increasing Marginal Cost

The second simulation employs the same cyclical density of consumers over utility flows, but in a market in which marginal costs are increasing, $c_2 > 0$. Figures $3A$ through $3D$ display the results of a typical simulation. This experiment highlights the second two points made in the introduction: that when marginal costs are increasing, the market exhibits countercyclical markups and demand fluctuations are propagated.

First, the main effect of increasing marginal cost is to increase price in booms (Figure $3A$) and therefore decrease quantity and smooth sales over the cycle (Figure $3B$). This effect generates propagation of increases in demand. Figure $3C$ demonstrates that sales are reduced because buyers postpone or accelerate purchase so as to move towards lower-price periods.

Second, the ability of consumers to substitute intertemporally robs firms of their market power during booms so that markups are countercyclical (Figure $2D$).[12] The elasticity of demand is highly dependent on local price variation.

[12] Because the costs of production are quadratic, the ratio of price to marginal cost declines in steady state with increases in the height of the distribution. Since this is not novel nor the interesting source of markup cyclicality in this paper, I report price less marginal cost as the markup.

When prices rise in booms this dampens the response of sales by causing buyers to move transactions to nearby periods.

Immediately before the boom, $u^+$ rises as consumers buy earlier than they would have if prices had stayed constant. Thus when the boom begins, sellers find themselves facing consumers who have higher amounts of their old goods left. In competing to sell to these consumers, firms lower their markups. Sellers only slowly increase their prices once in the boom, as $u^+$ falls towards its equilibrium level. At the end of the boom, consumers delay their purchases, and this decreases prices before the end of the boom and smooths the price and quantity fluctuation on the downside.

Durability and market power are crucial for the results of this subsection. That is, similar effects would be present in a model in which a representative agent purchases a durable good produced with a decreasing returns to scale technology. The timing of purchases and search structure provide a microfoundation for market power and an understanding of how the economy might generate predictable fluctuations in demand, as discussed in section 2.4.[13] It is also worth noting that the first effect emphasized in the previous subsection is still present, and is visible in the asymmetry of the figures. But in this example, the price-smoothing effect of consumer intertemporal optimization is more powerful than the price responses of firms to changes in the height of the density.

To summarize the implications of these two computational experiments, in markets in which the timing of purchases is important: 1) when marginal costs are flat, prices and markups are low when quantity increases at the beginning of booms; 2) when marginal costs are increasing, booms are smoothed and markups are countercyclical.

[13]This model can be viewed as providing a theory of relative intertemporal elasticities of demand. When timing rather than quantity is the choice, the ease of substituting timing, that is durability, makes demand more elastic.

### 3.3. Discussion of Assumptions

In this model, as the length of a time period goes to zero, the markup goes to zero (in equation (2.17), $P_{ss} \to 0$ as $\delta \to 0$).[14] This result follows from the same intuition as the well-known Coase (1972) conjecture.[15] Sellers cannot commit to keeping price high, so that as time periods become shorter, and follow one another more quickly, firms eventually sell to customers so rapidly that they run out of customers to sell to in any given interval of real time, and price falls to marginal cost.[16] However, this feature of the model results from assumptions made to preserve the tractability of the dynamic solutions rather then from the economics of the problem. More specifically, either a model in continuous time with a matching function or one in which search, rather than costing $c$, takes a fixed amount of real time, would preserve the dynamics of interest and be immune to a Coase critique.

The assumption that households never search can be significantly relaxed. An earlier version of this paper explicitly included a stochastic, match-specific value of a new good, $v_{ij}$. Sellers maintain some market power because buyers who are find a particular sellers' good an excellent match are quite price insensitive, however sellers price less aggressively because some buyers always have marginal matches. In this case, realistically, some buyers search across goods in each period. The model exhibits the same set of implications as those presented here.

It is worth noting that the model can be expanded to include a choice of amount as well as timing and not alter the qualitative implications of the model.

[14] Despite the fact that the size of the markup goes to zero as the length of a period goes to zero, the percent fluctuation in the markup over the cycle remains constant.

[15] See Bulow (1982)and Stokey (1981) for proofs and discussion of the robustness of the Coase conjecture. Depreciation can eliminate this result; see the results in Hamilton and Burke (1996), Bond and Samuelson (1984), and Bond and Samuelson (1987).

[16] Another way of looking at this thought experiment is that as the length of a time period goes to zero, fewer and fewer buyers purchase in any given period, so that sellers no longer worry about losing profits on their inframarginal customers. It is the presence of inframarginal customers which generates markups.

Nor is the assumptions of log utility crucial. Finally, adjustment costs can be made less severe so that households get some share of the value of a sold good without substantively altering the market dynamics.

An added possibility not explored in this model is the impact of fluctuations in the marginal utility of wealth or in effective depreciation rates. Such fluctuations however can be shown to lead to market dynamics that are quite similar to those in a market with durability and no fixed costs. An increase in the marginal utility of wealth acts like a decrease in $u_t^+$ so that prices increase and, with increasing marginal costs, the increase in sales is propagated.

# 4. Market Dynamics Under Collusion

## 4.1. Sellers

When sellers are able to collude, total profits are maximized by the sequence of prices which would be chosen by a monopolist who owned all the firms.[17] One can write this recursively as:

$$V_t(u_t^+) \equiv \max_{\{P_t\}} \left( P_t q_t(P_t, P_t) - c_1 q_t(P_t, P_t) - \frac{1}{2} c_2 q_t(P_t, P_t)^2 + R^{-1} E_t \left[ V_{t+1}(u_{t+1}^+) \right] \right). \tag{4.1}$$

However, it may not be possible to maintain this optimal level of collusion.[18] A firm deviating from the prescribed price sequence cuts its price and tries to steal consumers from the future demand of all firms. The usual punishment strategy involves all other firms setting prices to punish the defector in the subsequent period. Here however the optimal collusive arrangement can be maintained by

[17] I continue to assume that the colluding firms or monopolist take $E_t[P_{t+1}]$ as given when choosing $P_t$, as is standard. See for example Bils (1989). However, using a self-punishment scheme, it may be possible for firms to rationally internalize the effects of changes in today's price on consumer expectations of tomorrow's price. See Hamilton and Burke (1996).

[18] Rotemberg and Saloner (1986) argue that difficulty in maintaining collusion during booms causes prices to fall from monopolistic levels and leads to countercyclical markups.

subsequent pricing that makes the one-period payoff to defecting zero in the period of defection. After seeing any price below the collusive price, all firms choose the largest price that makes any consumers who purchased from the defector wish that they had not.[19] Given this punishment, these consumers therefore do not purchase and there is no incentive for the firm to defect in the first place.

Using the first-order condition and the envelope condition yields the following intertemporal Euler equation which is satisfied in the collusive equilibrium:

$$q_t(P_t,P_t)+R^{-1}E_t\left[(P_{t+1}-c_1-c_2q_{t+1}(P_{t+1},P_{t+1}))\frac{dq_{t+1}}{dP_t}\right]=(P_t-c_1-c_2q_t(P_t,P_t))\frac{-dq_t}{dP_t}.$$

When the firms consider a price increase they balance the additional return on the inframarginal buyers, $q_t(P_t,P_t)$ and the gain in profits on increased sales in $t+1$ against the decrease in profit from lost sales in the current period.

### 4.2. Market Equilibrium

Lemmas $1-3$ still apply when firms are colluding, but firms may choose sales equal to zero. While it is straightforward to keep track of these corner solutions, for simplicity, attention is restricted to fluctuations in demand that generate positive sales in every period.

Equation (2.13) determines quantity, so that the firm's first-order conditions can be rewritten to replace condition 3 as:

$$\begin{aligned}-R^{-1}\left[E_t[P_{t+1}]-c_1-c_2E_t[Q_{t+1}(P_{t+1})]\right] & +[P_t-c_1-c_2Q_t(P_t)] \\ & = \frac{Q_t(P_t)}{f_t((1-\beta)v+\beta E_t\left[P_{t+1}\right]-P_t)},\end{aligned} \tag{4.2}$$

where equation (2.13) gives $Q_t(P_t)$ and using the fact that:

$$\frac{dQ_t(P_t)}{dP_t}=-f_t(u_t^*)=-f_{t+1}(u_t^*-\delta)=-f_{t+1}(u_{t+1}^+)=-\frac{\partial Q_{t+1}}{\partial P_t}. \tag{4.3}$$

The first equality comes from equation (2.13), the second from equation (2.7), the third from equation (2.11), the final one from equation (2.13).

[19] Note that this equilibrium is not renegotiation-proof.

When sellers are colluding the steady state price, quantity and cutoff utility flow are:

$$\begin{aligned} P_{ss} &= c_1 + c_2\alpha\delta + \frac{\delta}{1-R^{-1}} \\ u_{ss}^{+} &= (1-\beta)(v-P_{ss}) - \delta \\ Q_{ss} &= \alpha\delta. \end{aligned} \tag{4.4}$$

**4.3. Demand Fluctuations**

When marginal cost is constant, prices are much less variable in the face of demand fluctuations than in the case in which firms are monopolistically competitive. Thus in this case, market dynamics do not alter the timing of purchases. Colluding firms internalize the effect of price changes today on sales tomorrow so that there is no incentive to cut prices to steal sales from one another's pool of potential future sales. Colluding firms do seek to shift sales forward because sales today are worth more than future sales, and, if demand is increasing, because inframarginal sales are less important than marginal sales.

Figures $4A$ to $4D$ display the results of a typical simulation when colluding firms have increasing marginal costs.[20] In this case, buyer intertemporal optimization acts to smooth price and quantity fluctuations. Sellers, on the other hand, try to keep markups roughly constant. They are willing to cut margins at the beginning of the boom, however, since getting buyers to buy early helps to keep costs lower as well as helping make sales sooner. Firms also raise prices at the end of the boom because losing some buyers to the future helps to keep costs low. Thus, this market structure predicts that markups should be lowest at the start of booms, when demand is increasing, as in the first case analyzed. Price and quantity dynamics mimic the dynamics of the noncollusive case with increasing marginal costs: prices rise in booms and quantity fluctuations are smoothed and propagated.

[20] Domowitz et al. (1987) also examine this case and argue that it implies a countercyclical markup.

## 5. Empirical Evidence

In this section, I investigate whether the effects that the model predicts are present for goods for which the timing of purchases and durability are important. Using industry data on prices, sales, and markups, three main hypotheses taken from the model simulations and tested. In industries that sell goods for which the ability of buyers to time their purchases is important: 1) price reactions to demand fluctuations are small (since buyer intertemporal optimization smooths prices); 2) when sales are increasing, prices and markups should be low (according to the first and third simulations); 3) markups should be countercyclical (when marginal costs are increasing).

### 5.1. The Data

The main data set employed is the National Bureau of Economic Research (NBER) productivity database, which contains annual data on industry inputs, sales, and prices at the level of the four-digit SIC code. The data set covers 450 industries from 1958 to 1991. Appendix $B$ contains further details on the data.

The second set of data comes from Bils and Klenow (1998). They report durability measures taken from the Bureau of Economic Analysis (BEA) and insurance company estimates which can be easily matched to the output of industries classified by four-digit SIC. This measure of durability is an imperfect measure of the concept of interest: how easily consumers can shift the purchase of a good through time. Bils and Klenow (1998) also use the Consumer Expenditure Survey (CEX) to construct Engel curves by good/industry for the same industries. However, they have difficulties with missing data, because many households in the data do not purchase every good. They report these fractions, which for their work represent a nuisance. For the present purposes, these measures are nearly ideal. Unfortunately, many items are not consumed by some households (e.g. people living in urban apartments and the goods produced by the lawnmower industry) Nevertheless, these data do represent a second imperfect measure of the concept of interest. From the reported statistics, I construct a variable that represents the percent of households which do not purchase a given good during a one year period. There is a high correlation between the two measures of the importance of timing. For example, refrigerators and freezers are not purchased by 92 percent of households and last on average 15 years. Tables B.1 and B.2 in Appendix *B* give the industry names, SIC codes, frequency of purchase and durability measures.

After eliminating industries for which frequency and durability data are not available, there are 109 industries. Due to a large number of outliers in the first year, I use data from 1959 to 1991 on each industry, leaving a total of 3597 observations.

Third, measures of industry four-firm concentration ratios are used to capture differences in cyclicality which are due to market power. Rotemberg and Saloner (1986) argue that collusion plays an important role in price smoothing. The data are at the 2-digit SIC level and are based on 1967 data, which is roughly the middle of the sample. The data, taken from Rotemberg and Woodford (1991), are reported in Appendix *B*.

Finally, in order to capture the demand-driven fluctuations in sales, I use the Hall-Ramey instruments: a dummy for the political party of the U.S. President, real Federal government defense spending, and the price of oil deflated by the GDP deflator. As discussed subsequently, I use these instruments interacted with the cross-industry measure of durability.

## 5.2. Evidence on Price Smoothness

To test whether prices are lower when demand is high, all regressions are performed in levels after log-detrending each time-varying series separately for each industry.[21] This procedure also has the advantage of removing fixed industry

[21] That is, I regress the logarithm of the variable in question on a constant and a time trend and then treat the residual as the datum. This procedure is done to make the regressions compatible with the literature inferring inferring markups from industry regressions (e.g. Basu

effects which might be correlated with the dependent variables. Since there is substantial industry-level serial correlation, all standard errors are calculated so as to be consistent in the presence of arbitrary within-industry serial correlation and heteroskedasticity.[22]

The first row of Table 5.1 shows the results of the regressing the real price of final sales[23] on real final sales, the percent of households who purchase the good, these two variables interacted, a constant, and a time trend.[24] A one percent increase in sales for a typical nondurable or frequently purchased good is associated with a 0.13 percent decrease in the real price of that good. A good purchased by only half of households in a year sees a typical decline in price of 0.08 percent. The negative relationship between sales and price represents the fact that some output increases are driven by supply-side factors such as increases in productivity and decreases in the cost of factor inputs. Note also that since I am using a subset of manufacturing industries and since industry output includes intermediate goods there is no reason for the average real price response to be zero.

and Fernald (1997)). Because the asymptotic distribution of the estimator relies on the number of industries going to infinity rather than the time dimension, estimation is robust to the presence of stochastic time trends.

[22] Standard errors are:

$$(X'X)^{-1}(\sum_{j=1}^{J} X_j' e_j e_j' X_j)(X'X)^{-1} \quad \text{and}$$

$$(\hat{X}'\hat{X})^{-1}(\sum_{j=1}^{J} \hat{X}_j' e_j e_j' \hat{X}_j)(\hat{X}'\hat{X})^{-1}$$

for ordinary least squares and two-stage least squares respectively. The letter $j$ indexes industries and $e_j \equiv Y_j - X_j\hat{\beta}$, a $T = 33$ by 1 vector.

[23] The price deflator for final shipments divided by the consumer price index (then log-detrended).

[24] The time trend and constant are included because the first observation has been dropped. No substantive results change when these two variables are omitted. If time dummies are included instead of a time trend similar conclusions concerning statistical significance of the interaction terms are reached, although magnitudes vary somewhat.

Table 5.1: Real Price Regressions

| | Sales | Sales* %NotBuy | Sales* cr4 | ΔSales | ΔSales* %NotBuy | ΔSales* cr4 | N*T |
|---|---|---|---|---|---|---|---|
| OLS | -0.13 | 0.10 | | | | | 3597 |
| | (0.03) | (0.03) | | | | | |
| IV | 2.63 | -3.19 | | | | | 3597 |
| | (1.26) | (1.55) | | | | | |
| | 2.53 | -3.24 | 0.32 | | | | 3465 |
| | (1.33) | (1.72) | (0.41) | | | | |
| | 2.47 | -2.99 | | -2.07 | 2.46 | | 3597 |
| | (0.73) | (0.90) | | (1.77) | (2.16) | | |
| | 2.69 | -3.63 | 0.44 | -4.34 | 1.23 | 8.47 | 3465 |
| | (0.99) | (1.40) | (0.55) | (3.68) | (2.49) | (9.65) | |

Note: All regressions also include a constant, a time trend, and the percent of households who do not purchase the good. The instrument set includes a time trend, the Hall-Ramey instruments, the durability of the industry's good, and the same interacted with the Hall-Ramey instruments. The instrument set for regressions with differenced right-hand-side variables also includes the Hall-Ramey instruments and interactions once lagged.

To isolate the response of price to demand fluctuations, I instrument the measures of sales with the Hall-Ramey instruments.[25] For two distinct reasons, the instruments also include the interaction of durability and the Hall-Ramey series. First, an aggregate demand shock does not increase demand equally across all industries. Economic theory suggests that demand increases much more for more durable goods, as expenditures must move large amounts to adjust stocks. The interaction term increases the explanatory power of the instruments significantly. Second, the frequency of purchase is only an imperfect measure of the concept of interest. Using durability instead of the frequency of purchase in the instrument set eliminates the attenuation bias resulting from this mismeasurement of the

[25] The regressions were also conducted using the real aggregate personal consumption expenditures series from the NIPA. All conclusions are robust to using this alternative instrument.

true concept of interest.

The second row of Table 5.1 shows the results of two-stage least squares estimation. The typical frequently-purchased good now sees a price rise of two and a half percent for each percentage increase in sales due to demand. For a good purchased by only half of households, this number falls to one percent, and the difference is statistically significant.[26] Including the measure of industry concentration ($CR4$) does not alter this conclusion, nor does including the first difference of sales and its interaction with the frequency of purchase measure. Thus the first implication of the theory is confirmed in the data: prices rise less in response to increases in demand for goods which are purchased less frequently.[27]

Rows 4 and 5 add the first difference of the sales variables to the regression in order to test whether, for infrequently purchased goods, prices are lower when quantities are increasing. Prices are lower when sales are increasing in general, and there is no statistically significant effect of frequency of purchase on this relationship.[28] Thus, the relationship predicted to hold for the subset of goods for which timing is important holds for all goods. It may well be that this additional general force which lowers prices when sales are increasing causes the price-smoothing effect to become the dominant difference between goods

[26] The large change in the coefficient on sales in the theoretically predicted direction is evidence of good instruments. Further, the fits of the first stages are good. In rows 2 and 3, %NotBuy is predicted with an $R^2$ of 0.74; sales with an $R^2$ of 0.09; sales interacted with %NotBuy with an $R^2$ of 0.12. First differenced sales are predicted with an $R^2$ of 0.04, and, when interacted with %NotBuy, with an $R^2$ of 0.05.

[27] Bils and Klenow (1998) do not include the interaction term and regress relative prices on relative labor-capital ratios in first differences and find insignificant and small relationships, even when they instrument. The main differences are that I am working in log-deviations from trend and more importantly that I use sales and an interaction term as the explanatory variables. A regression without the interaction term yields an insignificant coeficient on total sales.

[28] Similar results are obtained if the change in sales at $t+1$ is used instead of $t$ (without a change in the timing of the instrument set).

Table 5.2: MARKUP REGRESSIONS

| MARKUP SERIES | | SALES | SALES* %NOTBUY | ΔSALES | ΔSALES* %NOTBUY |
|---|---|---|---|---|---|
| $\mu 1$ | OLS | -0.12 | 0.12 | | |
| | | (0.39) | (0.63) | | |
| | IV | 0.31 | 0.29 | | |
| | | (0.63) | (0.93) | | |
| | IV | -0.23 | 0.23 | 1.78 | -2.48 |
| | | (0.73) | (1.00) | (2.32) | (3.26) |
| $\mu 2$ | OLS | 0.14 | -0.11 | | |
| | | (0.02) | (0.03) | | |
| | IV | 0.86 | -1.12 | | |
| | | (0.43) | (0.54) | | |
| | IV | 0.74 | -1.00 | -1.63 | 2.03 |
| | | (0.42) | (0.53) | (1.05) | (1.27) |
| $\mu 3$ | OLS | -0.04 | 0.01 | | |
| | | (0.01) | (0.02) | | |
| | IV | -0.98 | 1.14 | | |
| | | (0.40) | (0.49) | | |
| | IV | -0.96 | 1.11 | 0.02 | 0.08 |
| | | (0.25) | (0.31) | (0.47) | (0.56) |

Note: All regressions also include a constant, a time trend, and the percent of households who do not purchase the good. The instrument set includes a time trend, the Hall-Ramey instruments, the durability of the industry's good, and the same interacted with the Hall-Ramey instruments. The instrument set for regressions with differenced right-hand-side variables also includes the Hall-Ramey instruments and interactions once lagged.

for which timing is important and those for which it is not. Thus, prices are smoother for this subset of goods rather than lower when sales are increasing.

While prices are smoother for goods for which timing is important, there remains the possibility that marginal costs are heterogeneous across industries in just such a way as to generate smoother prices for less frequently purchased goods. That is, some combination of higher returns to scale and more elastic factor supplies implies that marginal costs are flatter or even decreasing for those goods which I find have smoother prices. To rule out this possibility, I perform a similar set of regressions using markups as the dependent variable. In doing so, I also seek to quantify the contribution of consumer intertemporal substitution of purchases to the cyclicality of the markup and thus the cyclical variability of production and sales. I construct three different measures of markups under three different sets of assumption, each used in previous work. The details are contained in Appendix $C$.

### 5.3. Evidence on Markups

Table 5.2 presents the results of regressions in which the dependent variable is the markup of price over marginal costs. The three pairs of rows each contain the results for one markup series. OLS regressions show markups to be roughly acyclical, falling between the findings of Domowitz, Hubbard and Petersen (1988) and Rotemberg and Woodford (1991).

Instrumental variables regressions capture the change in markups associated with demand-driven fluctuations. These regressions do not give clean answers about either markup hypothesis. First, markups seem slightly more countercyclical in response to demand fluctuations. Second, markups are more countercyclical for goods for which timing is more important only for the second markup measure. Evidence from the first markup series is inconclusive and evidence from the third shows less frequently purchased goods to have more procyclical markups. Third, the three series also give contradictory and weak evidence as

Table 5.3: Markup Regressions on Subsample

| Markup Series | | Sales | Sales* %NotBuy | ΔSales | ΔSales* %NotBuy |
|---|---|---|---|---|---|
| $\mu 1$ | IV | 1.25 | -1.41 | | |
| | | (0.73) | (0.91) | | |
| | IV | 1.27 | -1.42 | 0.09 | -0.14 |
| | | (0.60) | (0.77) | (0.53) | (0.85) |
| $\mu 2$ | IV | 1.58 | -1.49 | | |
| | | (0.89) | (0.77) | | |
| | IV | -1.52 | 1.61 | -0.25 | 0.40 |
| | | (0.73) | (0.85) | (0.82) | (0.96) |
| $\mu 3$ | IV | 0.94 | -1.06 | | |
| | | (0.54) | (0.63) | | |
| | IV | 0.97 | -1.10 | 0.23 | -0.20 |
| | | (0.41) | (0.48) | (0.40) | (0.47) |

See Notes for Table 5.2

to whether markups are lower when sales of infrequently purchased goods are increasing.[29]

Why are the results so unstable and inconclusive? One possibility is that differences in the construction of the three markup series generate different answers. However, it is also possible that the pattern of industry-specific returns to scale is confounding inference. In industries with short-run increasing returns to scale, real price stickiness may increase markups in booms. That is, as the theoretical sections discuss, the impact of frequency of purchase depends on the slope of the marginal cost curve. To test this, I reestimate the markup regressions on two subsamples of industries.

First, I use only those industries that are in 2-digit industries which Basu

[29] When the regressions include industry concentration interacted with the quantity dependent variable, and/or its first difference, these variables are never significant. As in the price regressions, the addition of industry concentration variables does not alter the significance or magnitude of other coefficients.

and Fernald (1997) find have decreasing returns to scale. The results for this subsample of industries are similar to the results reported in Table 5.2. This is not wholly surprising given that returns to scale is only one component of marginal cost, and differences in factor elasticities may well be more important. Thus, as a second cut, I examine only the subsample of industries in which the instrumented correlation of sales and price is positive.[30] This leaves 1815 observations. As is shown in Table 5.3, there is evidence that markups are less procyclical for infrequently purchased goods.[31] There is little evidence, however, of a consistent relationship between markups and whether demand is increasing or decreasing.

In sum then, cross industry evidence suggests that prices are smoother in industries where the timing of purchases is important. However, the timing variable is potentially correlated with the industry-specific slope of marginal cost. Evidence on markups, which attempt to measure both marginal cost and price, is not conclusive.

## 6. Conclusion

This paper presents a model in which consumers' ability to time the purchases of goods amplifies the elasticity of intertemporal substitution. When firms have some market power, fluctuations in consumer demand are fluctuations in the elasticity of demand and lead to price dynamics that are quite different from those in which households cannot time purchases. Specifically, this mechanism moves forward the start of booms and reduces markups at the start of and on the up-side of booms. Buyer intertemporal optimization opposes this force, generating real price stickiness and smoothing prices over time. When marginal

[30] That is, for each industry separately and using the usual instruments, I run price on sales, a time trend, and the percent of households not buying the good. Then I use only those industries for which the coefficient on sales is positive.

[31] There remains one puzzle however, which is that the relationship between price smoothness and the timing variable is reversed in this subsample.

costs are increasing, the markup of price over marginal cost is countercyclical, and demand fluctuations are smoothed over time, or propagated.

In industry data, as predicted by the model, the price responses to fluctuations in demand are smaller for those goods for which the timing of purchases is more important. But the evidence on the behavior of markups is less clear. Only a shred of evidence is found that markups are more countercyclical (or less procyclical) for those goods purchased most infrequently.

## References

**Adda, Jerome and Russell Cooper**, "Balladurette and Juppette: A Discrete Analysis of Scrapping Subsidies," *Journal of Political Economy*, Aug 2000, *108* (4), 778–806.

**__ and __** , "The Dynamics of Car Sales: A Discrete Choice Approach," July 2000. NBER Working Paper 7785.

**Arrow, Kenneth J., Theodore Harris, and Jacob Marschak**, "Optimal Inventory Policy," *Econometrica*, Jul 1951, *19* (3), 205–72.

**Bartelsman, Eric and Wayne Gray**, "NBER Manufacturing Database," December 1994. NBER Manuscript.

**Basu, Susanto**, "Procyclical Productivity: Increasing Returns or Cyclical Utilization?," *Quarterly Journal of Economics*, Aug 1996, (3), 719–51.

**__ and John G. Fernald**, "Are Apparent Productivity Spillovers a Figment of Measurment Error?," *Journal of Monetary Economics*, December 1995, *36* (1), 165–88.

**__ and __** , "Returns to Scale in U.S. Production: Estimates and Implications," *Journal of Political Economy*, Apr 1997, (2), 249–83.

**Benabou, Roland**, "Inflation and Markups," *European Economic Review*, 1992, *36*, 566–74.

**Bils, Mark**, "Pricing in a Customer Market," *Quarterly Journal of Economics*, November 1989, *104*, 699–718.

**__** , "Cyclical Pricing of Durable Goods," September 1991. University of Chicago GSB mimeo.

**__ and Peter J. Klenow**, "Using Consumer Theory to Test Competing Business Cycle Models," *Journal of Political Economy*, Apr 1998, *106* (2), 233–61.

**Bond, Eric W. and Larry Samuelson**, "Durable Good Monopolies with Rational Expectations and Replacement Sales," *Rand Journal of Economics*, 1984, *15*, 336–345.

**__ and __** , "The Coase Conjecture Need not Hold for Durable Good Monopolies with Depreciation," *Economic Letters*, 1987, *24*, 93–97.

**Bulow, Jeremy**, "Durable Goods Monopolists," *Journal of Political Economy*, 1982, *90*, 314–32.

**Caballero, Ricardo J.**, "Durable Goods: An Explanation for their Slow Adjustment," *Journal of Political Economy*, April 1993, *101*, 351–84.

**__ and Mohamad L. Hammour**, "The Cleansing Effect of Recessions," *American Economic Review*, December 1994, *84*, 1350–68.

**Caplin, Andrew J. and John Leahy**, "Aggregation and Optimization with State-Dependent Pricing," *Econometrica*, May 1997, *65* (3), 601–25.

**__ and __** , "Durable Goods Cycles," Feb 1999. NBER Working Paper 6987.

**Carleton, Dennis W.**, "A Critical Assessment of the Role of Imperfect Competition in Macroeconomics," Oct 1996. NBER Working Paper 5782.

**Carroll, Christopher D. and Wendy Dunn**, "Unemployment Expectations, Jumping (s,S) Triggers, and Household Balance Sheets," in Ben Bernanke and Julio Rotemberg, eds., *N.B.E.R. Macroeconomics Annual*, Cambridge: MIT Press 1997, pp. 165–217.

**Coase, Ronald**, "Durability and Monopoly," *Journal of Law and Economics*, 1972, *15*, 143–49.

**Conlisk, John, Eitan Gerstner, and Joel Sobel**, "Cyclic Pricing by a Durable Goods Monopolist," *Quarterly Journal of Economics*, August 1984, *99*, 489–505.

**Diamond, Peter A.**, "A Model of Price Adjustment," *Journal of Economic Theory*, 1971, *3*, 156–68.

**Domowitz, Ian, R. Glenn Hubbard, and Bruce Petersen**, "Market Structure, Durable Goods, and Cyclical Fluctuations in Markups," June 1987. Mimeo, Northwestern University.

**__ , __ , and __** , "Market Structure and Cyclical Fluctuations in U.S. Manufacturing," *Review of Economics and Statistics*, February 1988, *70*, 55–66.

**Eberly, Janice C.**, "Adjustment of Consumers' Durables Stocks: Evidence from Automobile Purchases," *Journal of Political Economy*, Jun 1994, *102* (3), 403–36.

**Fisher, Jonas D. M. and Andreas Hornstein**, "(S,s) Inventory Policies in General Equilibrium," *Review of Economic Studies*, 2001, *67* (1), 117–45.

**Grossman, Sanford and Guy Laroque**, "Asset Pricing and Optimal Portfolio Choice in the Presence of Illiquid Durable Consumption Goods," *Econometrica*, Jan 1990, *58* (1), 25–51.

**Hall, Robert E.**, "The Relation Between Price and Marginal Cost in U.S. Industry," *Journal of Political Economy*, October 1988, *96*, 921–47.

**Hamilton, Bruce W. and Mary Burke**, "The Coase Conjecture in Continuous Time: Imperfect Durability, Endogenous Durability, and Aftermarkets," April 1996. Johns Hopkins University Working Papers in Economics No. 362.

**Judd, Kenneth L.**, *Numerical Methods in Economics*, Cambridge, MA, M.I.T. Press, 1998.

**Phelps, Edmund S. and Sidney G. Jr. Winter**, "Optimal Price Policy under Atomistic Competition," in E.S. Phelps, ed., *Foundations of Inflation and Employment Theory*, New York, NY: Norton 1970.

**Rotemberg, Julio and Garth Saloner**, "A Supergame-Theoretic Model of Price Wars During Booms," *American Economic Review*, June 1986, *76*, 390–407.

__ **and Michael Woodford**, "Markups and the Business Cycle," in Oliver Jean Blanchard and Stanley Fischer, eds., *N.B.E.R. Macroeconomics Annual, 1991*, Cambridge, MA: MIT Press 1991, pp. 63–129.

**Stokey, Nancy**, "Rational Expectations and Durable Goods Pricing," *Bell Journal of Economics*, 1981, *12*, 112–28.

**Stolyarov, Dmitriy**, "Durable Goods Markets with Transactions Costs," 1998. University of Pennsylvania Manuscript.

# Appendices

## A. Proofs

In this appendix I restate and prove the lemmas in sections 2 and 3.

**Lemma 1.** *No search. In a symmetric equilibrium, no consumers search and*

$$V_t(u, p_{jt}) = Max\{u + \beta E_t[V_{t+1}(u - \delta, P_{t+1})]\ , v - p_{jt}\} \tag{A.1}$$

Proof. Since all firms charge the same price in every period, any search has a total expected gain of minus the search cost.⋄

**Lemma 2.** *Skimming property.* $u_{it} > u_{jt}$ *implies* $T_{ti} \leq T_{tj}$.

Proof. A buyer, $i$, with utility flow $u_{it}$ can exactly imitate the strategy of a buyer, $j$, with a lower utility flow, in which case $i$ receives the same return from purchasing but greater utility flow in every period before purchase. Thus $V_t(u, p_j)$ is weakly increasing in its first argument. Consider now the decision of each buyer as to whether to buy in $t$ or wait, as captured by equation (A.1). Given that both $u$ and $E_t[V_t(u-\delta, P_{t+1})]$ are greater for buyer $i$, the buyer with the lower utility flow, $j$, will always choose to purchase if buyer $i$ does, and may choose to do so when buyer $i$ does not.⋄

**Lemma 3.** $u_t^*$ *evolution. Provided that sellers sell to some consumers in every period,* $u_t^*$ *is defined by*

$$u_t^* = (1 - \beta)v + \beta E_t[P_{t+1}] - P_t \tag{A.2}$$

Proof. Consider consumers who are indifferent between purchasing in the current period and waiting. Allow the equilibrium to involve some of these indifferent consumers purchasing in the current period and some delaying their purchases.[32] Then it follows from Lemma (2), that all those with lower utility flows buy in the current period. Those with higher utility flows delay since $V_t(u, p_j)$ is increasing in $u$,

[32] Since these consumers are measure zero to firms, whether they all purchase, wait, or mix is irrelevant for the equilibrium.

$u + \beta E_t[V_{t+1}(u - \delta, P_{t+1})]$ is strictly increasing in $u$– the return to delaying is strictly increasing in $u$. If positive sales are made in every period, then those who are indifferent between purchasing and delaying in $t$ will purchase in $t+1$. $u_t^*$ is then defined by indifference in equation (A.1) as

$$\begin{aligned} v - P_t &= u_t^* + \beta E_t[V_{t+1}(u_t^* - \delta)] \\ &= u_t^* + \beta(v -_t E[P_{t+1}]) \end{aligned} \tag{A.3}$$

Rearranging yields equation (A.2).◇

**Lemma 4.** *Positive sales. If* $q_0 > 0$*, and* $p_t \geq c_1 \; \forall t$*, then* $q_t > 0 \; \forall t$*.*

Proof. First suppose market price were such that no sales were being made in period $t$. Profits to all sellers are zero. Then any individual seller can choose a price an arbitrarily small distance above the marginal cost at zero sales, $c_1$, and, if it makes positive sales, make a profit in $t$. Since there are an infinite number of sellers, selling to some consumers does not reduce expected future profits noticeably. Thus, any supposed market price greater than $c_1$ cannot coexist with zero sales. Suppose sales are made in period $t$ and in period $T > t+1$ and no sales are made between these dates. In period $T-1$, the highest utility flow buyer weakly refers buying in $T$ :

$$v - P_{T-1} \leq u_{T-1}^{+} + \beta(v - P_T). \tag{A.4}$$

At the end of period $t$, the highest utility flow consumer weakly prefers purchasing in $t$ to purchasing in all other periods including $t+1$ :

$$v - P_t \geq u_t^* + \beta(v - P_{t+1}). \tag{A.5}$$

Since zero sales are made during the period between $T$ and $t$, the highest utility flow individuals are the same and $u$ evolves as: $u_s^* = u_s^+ = u_{s-1}^* - \delta$. Using this to eliminate the utility flows from equations A.4 and A.5 yields:

$$v - P_{T-1} \leq -(T-1-t)\delta + (1-\beta)v + \beta P_{t+1} - P_t + \beta(v - P_T)$$

Note that in periods $t$ and $T$ sales are positive so that $P_t > c_1$, and $P_T > c_1$, while in periods $t+1$ and $T-1$, sales are zero so prices must be less than or equal to $c_1$. Making these substitutions preserves the inequality and yields:

$$0 \leq -(T-1-t)\delta, \tag{A.6}$$

which can only be true if $T = t + 1$, that is if there is no intermediate period with no sales.◇

**Lemma 5.** *Steady state equilibrium. The steady state always exists is uniquely determined by*

$$\begin{aligned} P_{ss} &= c_1 + c_2\alpha\delta + \delta \\ u_{ss}^{+} &= (1-\beta)(v - P_{ss}) - \delta \\ Q_{ss} &= \alpha\delta \end{aligned}$$

Proof: In order for $u_{ss}^{+}$ to remain constant, $Q_{ss}$ must equal $\alpha\delta$. Plugging this and the density function into the seller first-order condition (2.16) yields a unique $P_{ss}$. Equation (2.15) then gives a unique $u_{ss}^{+}$. There is thus a unique candidate for a steady-state equilibrium. Existence then follows from the fact that the seller profit function is concave, a fact easily checked. The proof for the collusive/monopolist case is identical and omitted.◇

## B. Data

A complete description of the NBER productivity database can be found in Bartelsman and Gray (1994). Its strength is careful attention to temporal consistency of industry and variable definitions. It includes measures of industry sales and inputs– including intermediate goods and raw materials– and price deflators for all inputs except the capital stock, where instead the database includes a deflator for new industry investment. Labor input is decomposed into production worker hours and nonproduction worker employment. The database and Bartelsman and Gray (1994) can be downloaded currently from the \pub\productivity directory on nber.harvard.edu by anonymous ftp. The measure of sales covers all sales by firms within the SIC code. That is, sales includes sales of non-final goods. Buyers of the intermediate goods may have somewhat different abilities to time purchases than buyers of the final consumer goods, which generate the measures of durability and frequency of purchase. All SIC codes are based on the 1972 categorization, as used by the NBER productivity database. Gross nominal production is calculated as total revenue less change in nominal inventories. Nominal inventories in $t-1$ are multiplied by the current inventories price deflator and divided by the lagged inventories price deflator to make the nominal change consistent. These variables and nominal payments to labor and intermediate goods are included in the NBER database.

The measure of frequency of purchase represents the percent of households not reporting any consumption expenditures on items in this SIC code during a one-year period (1986). The number is set to 0 for all nondurable industries. SIC codes defined as nondurable have these measures set to zero. These industries are all subindustries of 2-digit SIC code 20 and 21, food and kindred products and tobacco respectively. Tables B.1 and B.2 list the measures of infrequency of purchase and the measures of durability, and all nondurable goods are given a durability measure of zero. Durability measures are based on the life expectancy tables of a major U.S. insurance company. These life expectancies of goods are used by the company to adjust insurance claims for covered damages to these items and are weighted aggregates of slightly finer classifications. Durability measures for a subset of the industries (e.g. automobiles) are taken from Fixed Reproducable Tangible Wealth, 1925-89 by the Bureau of Economic Analysis. The reader is referred to Bils and Klenow (1998) for further details. The 109 industries that are used in the analysis include all subindustries of SIC codes 20 and 21, which are nondurable industries, and those set of industries employed by Bils and Klenow (1998).

Industry concentration measures, taken from Rotemberg and Woodford (1991), estimate the share of total final sales accounted for by the four largest firms in 1967, roughly the midpoint of the sample. The concentration ratios are at the 2-digit level except motor vehicles and other transportation equipment which are split. They are as follows: SIC 20 : 0.345, SIC 21 : 0.736, SIC 22 : 0.341, SIC 23 : 0.197, SIC 25 : 0.216, SIC 27 : 0.189, SIC 28 : 0.499; SIC 29 : 0.329; SIC 30 : 0.691, SIC 31 : 0.245, SIC 32 : 0.374, SIC 35 : 0.363, SIC 36 : 0.450, SIC 371 : 0.808, SIC $372-9$ : 0.501 ; SIC

Table B.1: DURABILITY AND INFREQUENCY OF PURCHASE, PART I

| SIC CODE | INDUSTRY | PERCENT NOT BUYING | DURABILITY (YEARS) |
|---|---|---|---|
| 2251 | WOMEN'S HOSIERY | 33.9 | 1.0 |
| 2252 | MEN'S HOSIERY | 49.2 | 1.7 |
| 2271 | WOVEN CARPETS AND RUGS | 82.6 | 11.1 |
| 2272 | TUFTED CARPETS AND RUGS | 82.6 | 11.1 |
| 2279 | CARPETS AND RUGS, NEC. | 82.6 | 11.1 |
| 2311 | MEN'S SUITS AND COATS | 53.3 | 4.1 |
| 2321 | MEN'S SHIRTS AND NIGHTWEAR | 34.9 | 2.7 |
| 2322 | MEN'S UNDERWEAR | 56.1 | 2.2 |
| 2327 | MEN'S TROUSERS | 34.6 | 2.7 |
| 2328 | MEN'S WORK CLOTHING | 34.6 | 2.7 |
| 2331 | WOMEN'S BLOUSES | 36.6 | 2.3 |
| 2335 | WOMEN'S DRESSES | 49.9 | 4.0 |
| 2337 | WOMEN'S COATS | 55.5 | 4.3 |
| 2341 | WOMEN'S UNDERWEAR | 32.7 | 1.8 |
| 2342 | BRASSIERS, GIRDLES, ETC. | 32.7 | 1.8 |
| 2361 | GIRL'S DRESSES AND BLOUSES | 82.9 | 2.3 |
| 2391 | CURTAINS AND DRAPES | 82.9 | 4.2 |
| 2511 | WOOD FURNITURE | 61.7 | 8.1 |
| 2512 | WOOD FURN. UPHOLSTERED | 61.7 | 8.1 |
| 2514 | METAL FURNITURE | 61.7 | 8.1 |
| 2515 | MATTRESSES AND BEDS | 89.3 | 15.0 |
| 2591 | BLINDS AND SHADES | 90.2 | 10.9 |
| 2711 | NEWSPAPERS* | 0.0 | 0.0 |
| 2721 | MAGAZINES* | 0.0 | 0.0 |
| 2731 | BOOKS PUBLISHING | 44.5 | 11.0 |
| 2732 | BOOKS PRINTING | 44.5 | 11.0 |
| 2834 | PRESCRIPTION DRUGS | 0.0 | 0.0 |
| 2911 | FUEL OIL AND GASOLINE | 0.0 | 0.0 |
| 2992 | MOTOR OIL | 0.0 | 0.0 |
| 3011 | TIRES | 35.2 | 3.0 |
| 3143 | MEN'S FOOTWARE | 49.0 | 2.5 |
| 3144 | WOMEN'S FOOTWARE | 31.6 | 2.6 |

Source: Bils and Klenow (1998).

*These industries have their "percent not buying" measures set to zero since these goods are not purchased by everyone, yet they are nondurable in the sense that one chooses to buy the current issue or not at all. None of the results change significance or sign with this adjustment.

Table B.2: Durability and Infrequency of Purchase, Part II

| SIC Code | Industry | Percent Not Buying | Durability (Years) |
|---|---|---|---|
| 3161 | Luggage | 88.5 | 17.5 |
| 3229 | Glassware | 84.3 | 10.0 |
| 3262 | China | 84.1 | 17.5 |
| 3263 | Cookware | 79.4 | 17.5 |
| 3524 | Lawnmowers | 85.7 | 7.5 |
| 3631 | Stoves and Ovens | 88.3 | 14.1 |
| 3632 | Refrigerators and Freezers | 92.2 | 15.0 |
| 3633 | Washers and Driers | 91.9 | 11.0 |
| 3634 | Portable Heaters | 87.7 | 11.3 |
| 3635 | Vacuum Cleaners | 91.2 | 9.5 |
| 3645 | Lamps | 83.9 | 16.7 |
| 3651 | TV's, VCR's, and Stereos | 53.3 | 11.9 |
| 3652 | Records and Tapes | 49.7 | 5.0 |
| 3661 | Telephones | 80.7 | 7.1 |
| 3711 | Automobiles | 91.2 | 10.0 |
| 3713 | Light Trucks and Vans | 97.1 | 8.0 |
| 3732 | Boats | 99.1 | 10.0 |
| 3751 | Motorcycles | 90.2 | 8.6 |
| 3792 | Trailers and Campers | 98.6 | 8.0 |
| 3851 | Eyeglasses and Contacts | 68.3 | 10.0 |
| 3861 | Film and Photo Equip. | 39.2 | 6.7 |
| 3873 | Clocks and Watches | 64.1 | 15.5 |
| 3911 | Jewelry | 55.8 | 5.5 |
| 3914 | Silverware | 91.4 | 27.5 |
| 3931 | Musical Instruments | 91.5 | 13.0 |
| 3944 | Games and Toys | 41.9 | 5.0 |

Source: Bils and Klenow (1998).

38 : 0.478.

## C. Constructing Markups

Measuring markups is a difficult and controversial undertaking. Three different constructed measures of markups are analyzed, each based on a slightly different set of assumptions. The starting point for all of the measures is a standard production function in which real gross output is produced from labor input, capital, and intermediate goods:[33]

$$Y = AF(L, K, M). \tag{C.1}$$

Time and industry subscripts are omitted for notational simplicity. Assuming that firms are price takers in factor markets and that factors are freely variable, cost minimization implies:

$$\frac{F_J J}{Y} = \lambda \frac{P_J J}{PY}, \tag{C.2}$$

where $P_J$ is the price of input $J$, $\lambda$ is the Lagrange multiplier on the output constraint, and $J$ is any factor for which the marginal product, $F_J$, is strictly positive and bounded for strictly positive and bounded levels of $J$. If this is true for all inputs, $\lambda = \mu$, the markup, defined as price divided by marginal cost. Then, the elasticity of output with respect to each factor input equals the markup times the ratio of the input's cost to total revenue.[34] Finally, define $\gamma$ as the degree of returns to scale of the production function so that:

$$PY = \frac{\mu}{\gamma} \sum_J P_J J. \tag{C.3}$$

[33] I experimented with including production and nonproduction workers as separate inputs. Conclusions reached throughout this alternative analysis were similar if not slightly more favorable to the theory being tested. I chose to report this method since the only measure of compensation of production workers is wages, which is likely significantly more cyclical than total compensation of production workers. Thus, I use total payroll for all workers to measure the cost of labor input.

[34] Hall (1988) originates the use of this methodology to estimate marginal costs (and thus markups). See Basu and Fernald (1995) for a discussion of this general methodology and the importance of using gross output data.

The first measure of markups considered is derived from three assumptions. First, $\gamma$ is assumed constant across time for each industry. Second, on average there are no pure profits in each industry, so that revenues equal costs for each industry over the sample: $\frac{1}{T}\sum_t PY = \frac{1}{T}\sum_t \left(\sum_J P_J J\right)$. Finally, capital is assumed quasi-fixed. Rearranging equation (C.3) and taking log-deviations from trend, the first markup measure is:

$$\widehat{\mu 1} = \frac{PY - \overline{PY} - \left(P_L L - \overline{P_L L}\right) - \left(P_M M - \overline{P_M M}\right)}{\overline{PY}}, \tag{C.4}$$

where $\widehat{x} \equiv \frac{x-\bar{x}}{x}$ and $\bar{x}$ is the log-trend in $x$. While the assumption of capital fixity is rather crude, because the real capital stock does not move much over the cycle, the empirical effects of assuming fixity are small.[35]

The second measure of markups is constructed by adding the additional assumption that the marginal product of labor is proportional to the ratio of labor input to real output. This is true, for example, of a Cobb-Douglas production function. Substituting into equation (C.2) and taking log-deviations from trend yields:

$$\widehat{\mu 2} = \left(\widehat{\frac{PY}{P_L L}}\right), \tag{C.5}$$

Finally, I follow the method of Benabou (1992) that extends the procedure of Rotemberg and Woodford (1991) to include intermediate goods. First, one assumes that intermediate goods are used in strict proportion to output and that the production function exhibits constant returns to scale but there may be fixed costs. Therefore equation (C.2) applies only to capital and labor, $\lambda = \frac{\mu}{1-\mu S_M}$ where $S_M$ is the share of intermediate goods costs in total revenue, and equation (C.3) has $\gamma = 1$. Next, one assumes that free entry leads to the elimination of pure profits, so that the average

[35] Basu (1996) assumes freely variable capital and argue that the effects of fixity are likely small. The arguments apply here in reverse. Further, an alternative approach is to assume that capital is freely variable and construct the nominal cost of capital. This can be done rather crudely under the assumption that capital is freely variable, so that $(P_K K)_t = P^I_{t-1}K_{t-1} + P^I_t I_t - P^I_t K_t$ where $P^I$ is the price deflator for new investment, and $I$ is new investment. When tried, the results are similar to those reported for $\mu 1$, but with slightly larger standard errors, due most likely to the additional error that the noisy measure of the return to capital introduces.

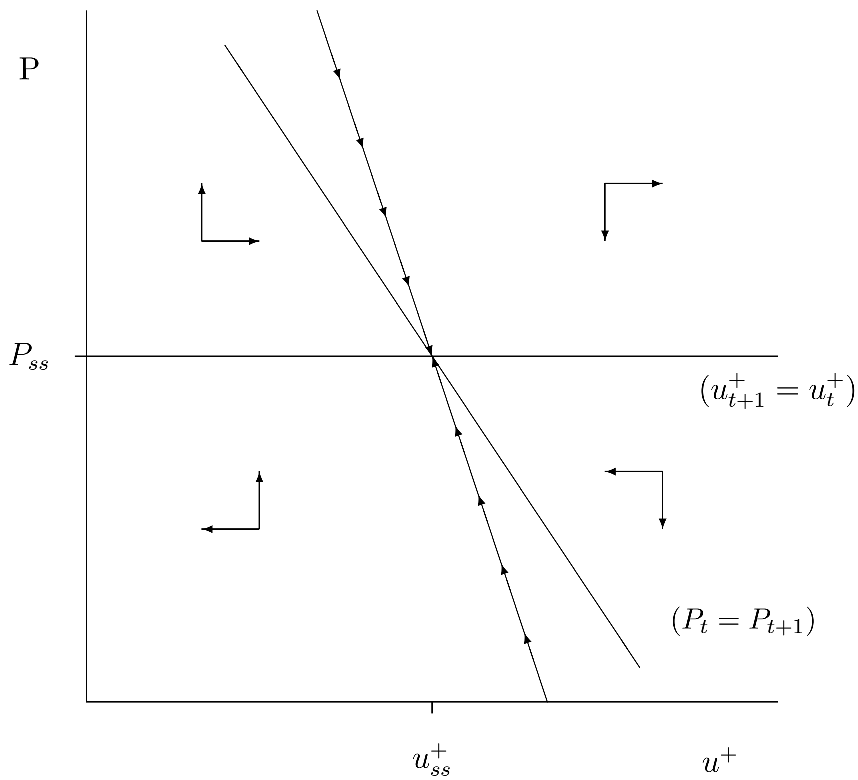
cost shares of each input for each industry sum to one. Finally, one assumes that the cost share of labor in value added is equal to one minus the cost share of capital in value added. This allows one to avoid having to calculate a cost of capital series, and this assumption can be justified by assuming that capital and labor are combined using a Cobb-Douglas technology. Taking log-deviations and rearranging (see Benabou (1992)), the third markup series is:

$$\widehat{\mu 3} = \frac{1}{1 + S_M(\frac{\mu}{1-S_M} - 1)} \left[ -\widehat{S_H} - (1 - S_M - \mu) \left( S_H \widehat{H} + S_K \widehat{K} + S_M \widehat{S_M} \right) \right]. \quad \text{(C.6)}$$

As before, all hatted variables are log deviation from trend (for each industry), while variables without hats represent sample averages (again by industry). $S_M$, $S_H$, $S_K$ represent the share of intermediate goods, labor, and capital in total revenue; and $\mu$ is the average markup. The only difference between this equation and equation (8) in Benabou (1992) is the term $\frac{\widehat{S_H}}{1-S_M}$ and using $\frac{\widehat{S_M}}{1-S_M}$ instead of the price series employed in Benabou (1992). The first is correcting a typo; the second substitution is taken because nominal shares are likely to be better measured than price deflators. Steady state and log-deviations can all be calculated from the NBER productivity database, except for the average markup which is set to 1.20 based on recent consensus.[36]

[36] See for example Basu (1996).

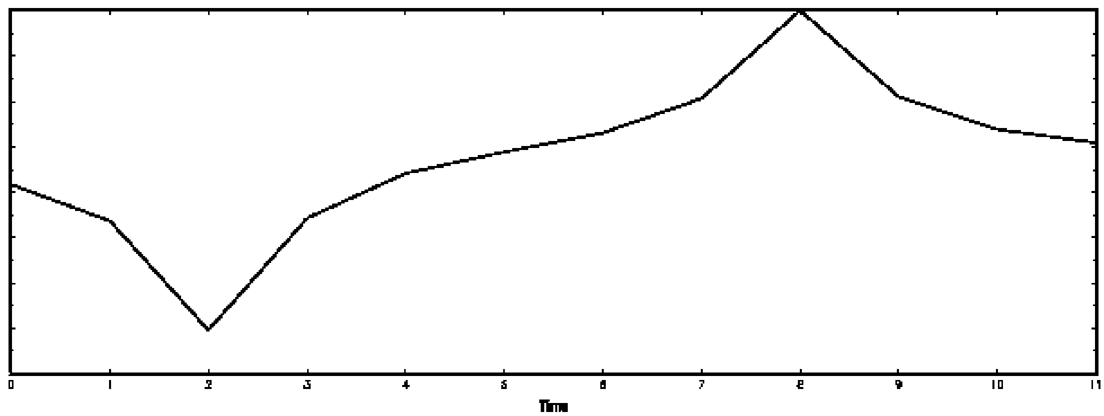
# Figure 1



# Figure 2

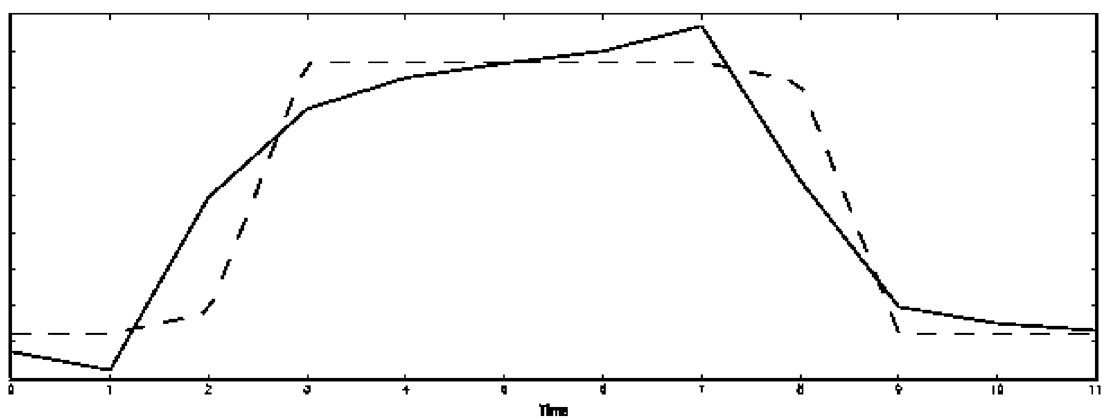
## Panel A

Price over a Cycle



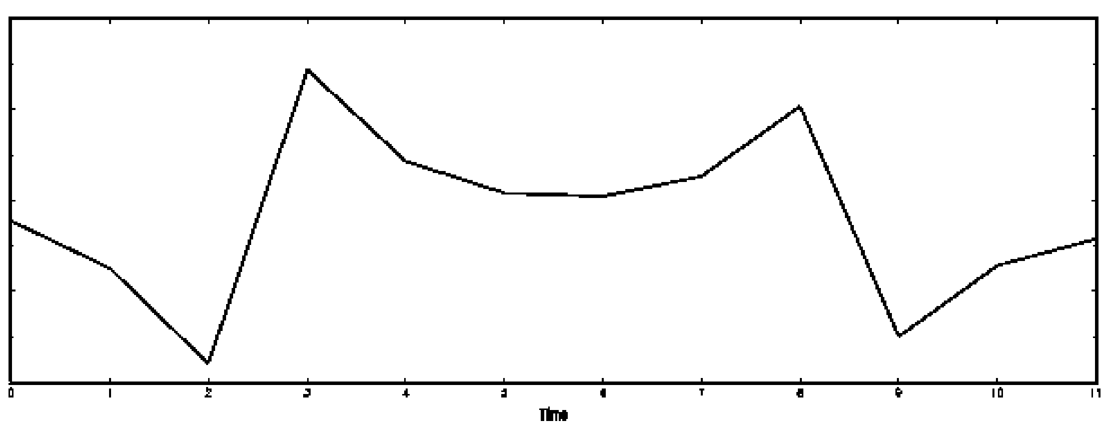

## Panel B

Actual Sales and Sales at Steady-State Price



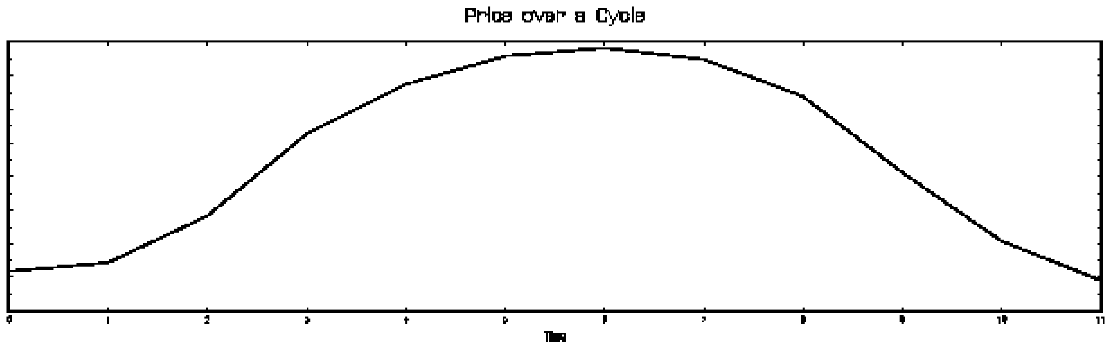

## Panel C

Cutoff Utility Flow at Start of Period



# Figure 3

## Panel A

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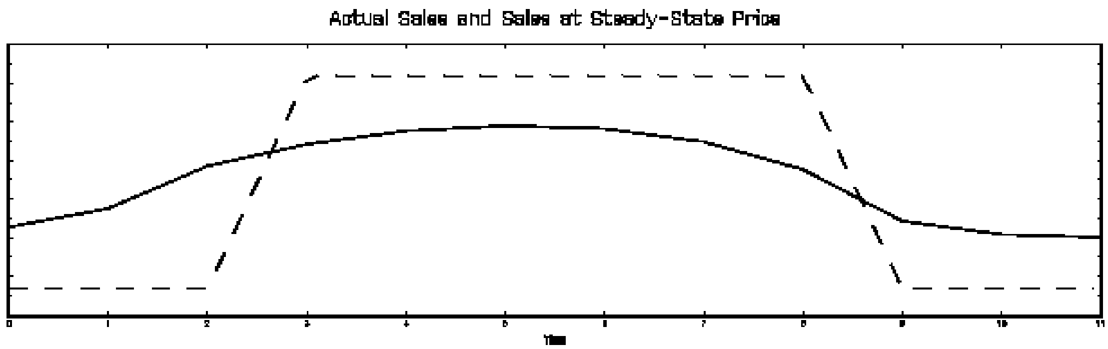
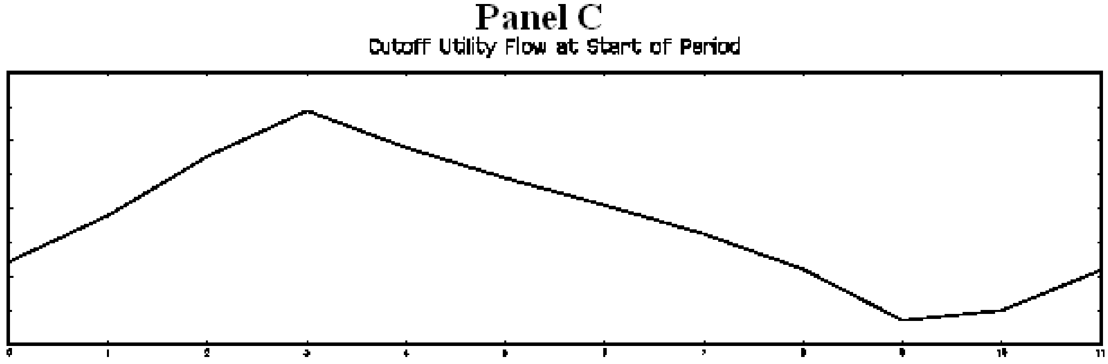
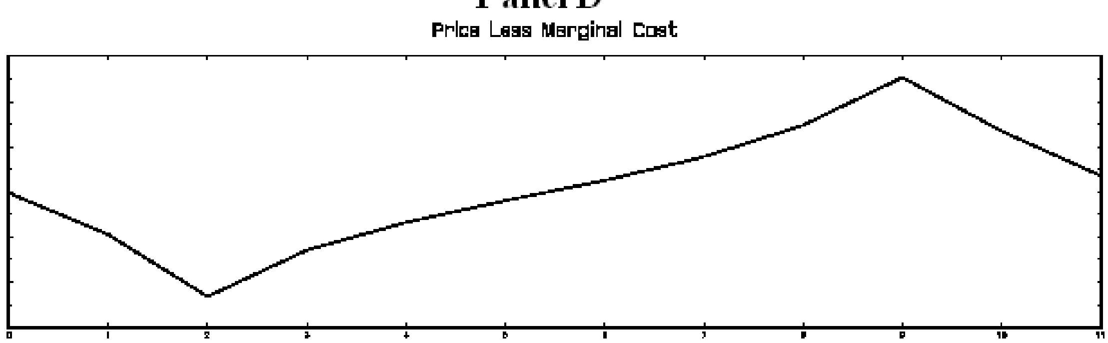



## Panel C

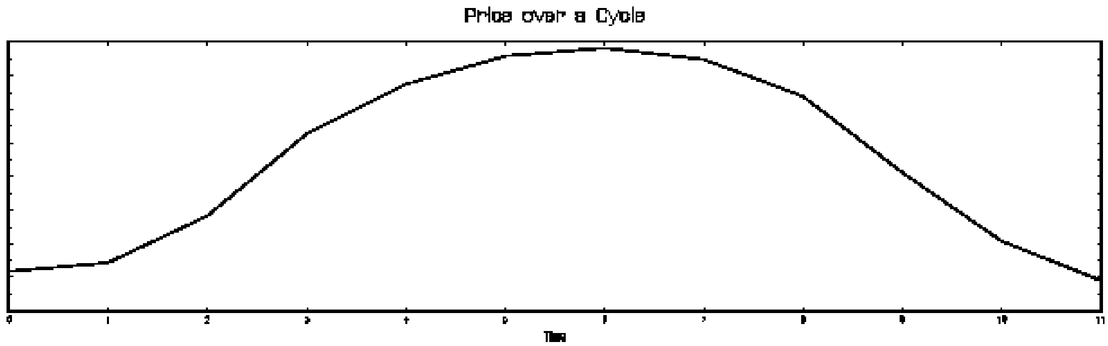



## Panel D

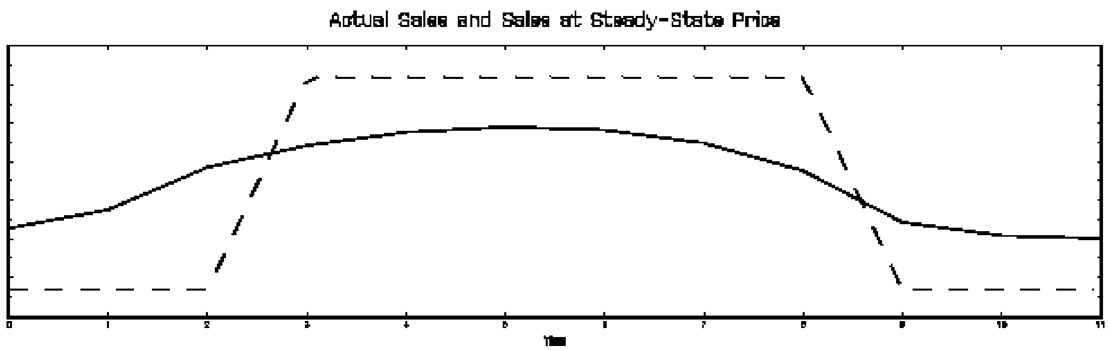


# Figure 4

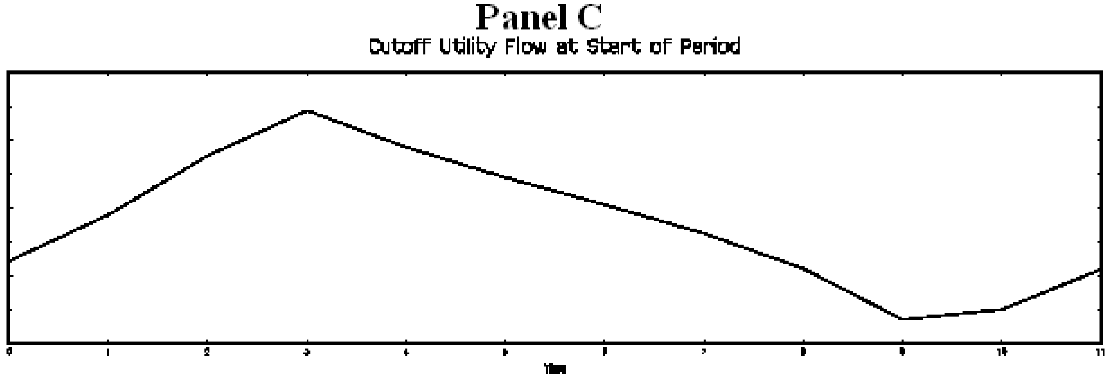
## Panel A




## Panel B




## Panel C




## Panel D