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PLANNED OBSOLESCENCE AS AN ENGINE OF
TECHNOLOGICAL PROGRESS

by

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Planned Obsolescence as an Engine of Technological Progress

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Critics of capitalism contend that many products are designed to have uneconomically short lives, with the intention of forcing consumers to repurchase too frequently. This phenomenon is commonly referred to as "planned obsolescence." In this paper, we show that planned obsolescence may be a necessary condition for the achievement of technological progress and that a pattern of rapidly deteriorating products and fast innovation may be preferred to long-lasting products and slow innovation.

Keywords: Durability, Innovation, Technological Progress.

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1. Introduction

Critics of capitalism contend that many products are designed to have uneconomically short lives, with the intention of forcing consumers to repurchase too frequently. This phenomenon is commonly referred to as "planned obsolescence." Coase (1972) and Bulow (1986) argued that wastefully short durability is the cost imposed by the durable goods monopolist to overcome the time consistency problem (see Stokey (1981), Bulow (1982), and Gul, Sonnenschein, and Wilson (1986)).

The purpose of this paper is to challenge the prevailing view and argue that planned obsolescence may be a necessary condition for the achievement of technological progress. If products are too durable, potential innovators may lack the incentives to invest in the development of a new technology and the economy may stagnate as a result.

Specifically, we develop a model of an overlapping generations economy, in which the introducer of a new technology enjoys a temporary monopoly position, which is subsequently eroded by entry of imitators. Therefore, for innovation to occur, the number of potential buyers in the market at the time of innovation must be sufficiently large to cover development costs.

In our framework, this market potential is endogenously determined by the longevity of previously produced models. When the previously produced generation of products is still in place at the time that innovation is scheduled to occur, the market potential is smaller than when earlier models are ripe for replacement and therefore may be unable to sustain further innovation.

We identify two perfect foresight equilibria. In the first equilibrium, new technologies are continually being developed. It is shown that this equilibrium must be characterized by the production of non-durable products only. Thus, innovation and the production of durable products are incompatible. In the second equilibrium, products

are designed to last too long; consequently innovation never occurs and the economy stagnates. We derive the technological conditions under which: (1) the unique outcome involves continuous innovation, (2) the unique outcome is perpetual stagnation, (3) both outcomes are equilibria.

In the third case, innovation is the efficient outcome, but the type of equilibria which obtains depends on whether the social norm is to produce short-lived or long-lasting products; If the social norm is short-lived products, the economy flourishes through a sequence of technological improvements, while if the social norm is long-lasting products, the economy is condemned to perpetual stagnation.

Section 2 describes the model, while section 3 addresses efficiency. In section 4, we characterize market equilibria. Section 5 is a comparison of efficient and equilibrium outcomes and section 6 provides brief conclusions.

2. The Model

We consider a discrete time overlapping generations economy, where at each date t , $t = 1, 2, \dots$, the economy consists of two cohorts: the young of generation $\tau = t$ and the old of generation $\tau = t - 1$. The number of new consumers entering the market each period is normalized to one.

2.1 Consumers

A consumer receives utility from a single manufactured product. This product is defined by two characteristics: durability and quality. The first characteristic refers to the technical feasibility of manufacturing either non-durable (ND) or durable (D) products. The former provides service for only one period, while the latter provides identical services for two periods.

The quality of the product depends on the vintage of technology with which it

is produced. Specifically, we assume that the consumer's reservation price for a non-durable unit of the i th technological innovation is $\lambda^i v$, $\lambda > 1$, where $v > 0$ is a constant that represents the utility from the 'initial' technology. λ represents the speed of technological progress; the greater λ is, the greater the rate of technological progress. Ignoring discounting, the consumer's reservation price for a durable unit produced with the i th technological innovation is $2\lambda^i v$. The i th technological innovation is referred to as the i th generation of technology.

2.2 Firms

The market consists of a large number of firms, each of which is capable of producing an unlimited quantity of either a durable or a non-durable product of the existing technology. In each period, one of the firms in the market is randomly endowed with the knowledge to develop a new technology.¹ The new technology is costly to develop and we denote this development cost by $F > 0$. If a firm innovates it receives a patent right for that period. After one period, the patent right expires and products using this technology (both durable and non-durable) are sold competitively, i.e., at cost. The innovator is restricted to producing either a durable or a non-durable product, but not both types.²

For simplicity, we assume that the marginal cost of production does not vary with technological change. The marginal cost of producing a durable (non-durable) unit is c^D (c^{ND}), $c^D > c^{ND}$. The cost of producing a durable is no greater than twice the cost of producing a non-durable, i.e., $c^D \leq 2c^{ND}$. Thus, we allow for economies of scale in the 'production' of durability.

¹This endowment can be viewed as the outcome of a patent race.

²A development opportunity which is not exploited is lost by the innovator.

3. Efficiency

We define the economy's period t total surplus as the sum of the utility of the young generation ($\tau = t$) at period t and the utility of the old generation ($\tau = t-1$) at period t , less production and development costs. We restrict attention to the following four stationary paths.

1. Continuous innovation of non-durable products.
2. Continuous innovation of durable products.
3. No innovation (stagnation) and durable products.
4. No innovation (stagnation) and non-durable products.

DEFINITION 1 *A stationary path is said to be efficient if it leads to the highest total surplus among all stationary paths in every period.*

Note that our definition of efficiency is quite demanding since it requires total surplus to be higher in *every period*.

If innovation occurs in each period (so the technology and the time indices coincide), the period t surplus from the production (and consumption) of state of the art non-durable products is

$$S_t^1 = 2\lambda^t v - 2c^{ND} - F,$$

since both the old and young purchase a non-durable valued at $\lambda^t v$ which costs c^{ND} to produce and F to develop. Similarly, the period t surplus from continuous innovation and the production of durable products (which are sold to the young only) is

$$S_t^2 = \lambda^{t-1} v + \lambda^t v - c^D - F.$$

The term $\lambda^{t-1} v$ in the preceding expression is the service received by the old generation from the purchase of a state of the art durable in the previous period, while $\lambda^t v$ is the

service received at time t by the young from the purchase of a state of the art durable. Since the new product is only sold to the young, the production cost is c^D , while the development cost is F . The period t surplus from continuous innovation and the production of non-durables exceeds the period t surplus from continuous innovation and the production of durables whenever $S_t^1 > S_t^2$, i.e., whenever

$$\lambda^{t-1}(\lambda - 1)v > 2c^{ND} - c^D.$$

We assume that this inequality holds for all periods, i.e.,

Assumption 1

$$(\lambda - 1)v > 2c^{ND} - c^D.$$

Assumption 1 states that if innovation takes place continuously, it is efficient to produce non-durable products.³ In other words, the gain from the acceleration of technology, $(\lambda - 1)v$, exceeds the short term cost disadvantage, $2c^{ND} - c^D$.

If innovation never takes place, the surplus when durable products are produced, $2v - c^D$, is greater than the surplus when non durable products are produced, $2v - 2c^{ND}$. Thus, if no innovation takes place, it is efficient to produce durable products.

Continuous innovation and the production of non-durables yields higher period t total surplus than no innovation and the production of durable products whenever^{4,5}

$$F < 2(\lambda^t - 1)v + c^D - 2c^{ND}.$$

³Clearly Assumption 1 implies that $S_t^1 > S_t^2$ at every $t \geq 1$.

⁴The former yields $2\lambda^t v - 2c^{ND} - F$ while the latter yields $2v - c^D$.

⁵Note that since λ^t is growing over time, this equation must eventually hold, implying that no innovation and the production of durables will never yield higher surplus than innovation and non-durables in every period.

We say that continuous innovation of non-durable products is the efficient outcome if it yields higher surplus than no innovation and the production of durables in every period, i.e., if⁶

$$F < 2(\lambda - 1)v + c^D - 2c^{ND}. \quad (1)$$

The preceding discussion is summarized by the following lemma.

Lemma 1 *Suppose that the development costs are sufficiently small so that (1) holds. Then, continuous innovation of non-durable products is the efficient outcome.*

4. Equilibrium

An equilibrium specifies at each period whether an innovation occurs, what type of good (durable or non-durable) is produced by the innovator, and the price of the good produced by the innovator. (Recall that in the period in which it is developed, a product embodying the new technology will be monopoly priced, and competitively priced in subsequent periods.) We analyze perfect foresight equilibria, so that given the future paths of innovation and prices, each consumer maximizes her utility and each firm maximizes its profit. We restrict attention to equilibria in which either innovation occurs each period or never occurs at all and if innovation occurs, the product type (non-durable or durable) produced by the innovator is the same in each period. Thus, there are four possible equilibria to consider, corresponding to the stationary paths discussed in the previous section:

1. Continuous innovation of non-durable products.
2. Continuous innovation of durable products.
3. Stagnation and durable products.

⁶Clearly equation (1) implies the previous equation.

4. Stagnation and non-durable products.

Note that if innovation occurs in each period, the technology and the time indices coincide. We thus proceed with the time index only. Subsection (4.1), analyzes innovation equilibria and subsection (4.2) analyzes stagnation equilibria.

4.1 Equilibrium with Continuous Innovation

The purpose of this section is to characterize equilibria with continuous innovation and to identify the conditions under which they exist. The main result is that innovation is only compatible with the production of non-durables. The remainder of this section is devoted to proving this result.

Proposition 1 *1. An equilibrium in which innovation occurs continuously and non-durables are produced by innovators, exists if only if $2(\lambda - 1)v \geq F$.*

2. An innovation equilibrium with the production of durables does not exist.

Proof. We now prove the first part of the proposition. Then, in the appendix, we prove the second statement, i.e., that innovation is incompatible with the production of durables.

Suppose that in equilibrium innovation takes place continuously and that innovators always produce non-durables. We denote by $p^{t,ND}$ the period t price of a non-durable product embodying the newest technology (the technology developed in period t). In every period t , the *old* consumers in period t will purchase the product embodying the new technology if the utility from purchasing it is at least as large as the utility from purchasing a non-durable product embodying the previous technology product at a competitive price of c^{ND} , i.e., if

$$\lambda^t v - p^{t,ND} \geq \lambda^{t-1} v - c^{ND}. \quad (2)$$

(Since $c^{ND} < c^D$, the old will never want to buy a durable of the old technology.)

The following options are available to a *young* consumer in period t :

- a. Purchase the newest available technology in each period of her life. In this case, her lifetime utility is

$$u^a = \lambda^t v - p^{t,ND} + \lambda^{t+1} v - p^{t+1,ND}.$$

- b. Purchase a non-durable unit of the old technology (i.e., the technology developed in period $t - 1$) in her first period, and the state-of-the-art technology (i.e., developed in period $t + 1$) in her second period. In this case, her lifetime utility is

$$u^b = \lambda^{t-1} v - c^{ND} + \lambda^{t+1} v - p^{t+1,ND}.$$

- c. Purchase a non-durable unit of the new technology (i.e., the technology developed in period t) in her first period, and purchase a non-durable unit of the old technology in her second period. In this case, her lifetime utility is

$$u^c = \lambda^t v - p^{t,ND} + \lambda^t v - c^{ND}.$$

- d. Purchase a non-durable of the old technology at each period of her life. Then, her utility is

$$u^d = \lambda^{t-1} v - c^{ND} + \lambda^t v - c^{ND}.$$

- e. Purchase a durable of the old technology at her first period. In this case, her utility is ⁷

$$u^e = 2\lambda^{t-1} v - c^D.$$

⁷Clearly, she would never buy an outdated durable in the first period if she plans to make any purchase in the future.

For this type of equilibrium to exist, the young in each period must prefer option (a) over the others. That is, $u^a \geq \max\{u^b, u^c, u^d, u^e\}$. By Assumption 1, $u^d > u^e$ while $u^a \geq \max\{u^b, u^c, u^d\}$ if and only if equation (2) holds. Thus, a necessary and sufficient condition for (a) to be the most preferred option by each generation of young consumers is that equation (2) holds for every t ; this is the same condition which is necessary and sufficient for the old to purchase the new technology. Since the monopoly will extract the maximum possible surplus, the equilibrium period t price of the t th technology is solved from (2) and is given by

$$p^{t,ND} = \lambda^{t-1}(\lambda - 1)v + c^{ND}. \quad (3)$$

Thus, the profit earned by a period t innovator selling a non-durable product is given by

$$\pi^{t,ND} = 2\lambda^{t-1}(\lambda - 1)v - F. \quad (4)$$

Profits are non-negative in each period if $2(\lambda - 1)v \geq F$.

In order for this to be an equilibrium, we must show that an innovator earns higher profits by producing a non-durable rather than a durable. The profit of innovating and producing a durable depends on whether the product is sold to both cohorts or just to the young. There are two types of deviations to consider: pricing the durable to sell both cohorts or pricing the durable to sell to the young only. In order to sell to both cohorts, the price has to be low enough to induce the old to purchase it. Since the old will only receive a single period's services from the product, the maximum price, p' , that they are willing to pay for a durable embodying the state of the art technology is implicitly defined by $\lambda^t v - p' = \lambda^{t-1} v - c^{ND}$. Solving this equation for p' , the profit of the firm from following this strategy is given by

$$2\lambda^{t-1}(\lambda - 1)v - 2(c^D - c^{ND}) - F < \pi^{t,ND}. \quad (5)$$

Thus this deviation is unprofitable. Consider the deviation where the innovator prices a durable to sell to the young only. Then the young's utility from purchasing this good

at price p'' without making an additional purchase in the next period is $2\lambda^t v - p''$. Since option (d) is always available to the young, p'' cannot be higher than $\lambda^{t-1}(\lambda - 1)v + 2c^{ND}$. In this case, the innovator's profit is given by

$$\lambda^{t-1}(\lambda - 1)v + 2c^{ND} - c^D - F < \pi^{t,ND}. \quad (6)$$

where the inequality follows from Assumption 1. This concludes the proof that if non-durables are produced, a necessary and sufficient condition for the existence of an innovation equilibrium is $2(\lambda - 1)v \geq F$. The proof that innovation occurs only if non-durables are produced is found in the appendix. Q.E.D

4.2 Stagnation Equilibria

In this subsection we derive conditions for the existence of equilibria characterized by perpetual stagnation. It is shown that stagnation must be accompanied by the production of durable products only. The rest of this subsection is devoted to proving this result.

Proposition 2 *1. A stagnation equilibrium exists if and only if:*

$$F > \max\{(\lambda - 1)v + 2c^{ND} - c^D, 2(\lambda - 1)v - 2c^{ND}\}.$$

2. In such an equilibrium, only durables are produced and all firms earn zero profits.

Proof. It is first shown that stagnation is incompatible with the production of non-durables. This follows directly from the fact that in the absence of innovation, all products are sold competitively (at cost). Thus, the utility received by a young consumer from purchasing a durable is $2v - c^D$, while her utility from purchasing a non-durable at each period is $2v - 2c^{ND}$. Since $2c^{ND} \geq c^D$, a young consumer maximizes utility by purchasing a durable product. This shows that a stagnation equilibrium is characterized by the production of durable products. To establish the existence

of such an equilibrium, it must be shown that no potential innovator can profit by deviating and innovating.

There are four possible deviations to consider.

(D.1) innovating by producing a durable and selling to both generations

(D.2) innovating by producing a durable and selling to the young only.

(D.3) innovating by producing a non-durable and selling to both generations.

(D.4) innovating by producing a non-durable and selling to the young only.

We consider each deviation in turn.

Profit from Deviation (D.1): Since the old already have a unit which provides v costlessly, the most they are willing to pay for a unit, durable or not, of the new technology is $\lambda v - v = (\lambda - 1)v$. To sell to both generations, this is the maximum which may be charged. Thus, the maximum profit earned by the innovator from deviation (D.1) is:

$$\pi^1 = 2(\lambda - 1)v - 2c^D - F.$$

Profit from Deviation (D.2): Given deviation (D.2), young consumers have the following options:

- i. buy the new (durable) technology in the first period
- ii. buy a durable of the old technology in the first period
- iii. buy a non-durable of the old technology in the first period and a non-durable unit of the new technology in the second period, when it will be available at the competitive price.

Exercising option (i) gives a utility of:

$$2\lambda v - \tilde{p},$$

where $\tilde{p}$ is the innovator's price. Exercising option (ii) gives a utility of:

$$2v - c^D$$

Finally, exercising option (iii) gives:

$$v + \lambda v - 2c^{ND}$$

By Assumption 1, the utility from (iii) is greater than the utility from (ii). Thus, the innovator will sell the durable to the young if and only if the utility from (i) is greater than that from (iii), i.e., iff:

$$2\lambda v - \tilde{p} \geq \lambda v + v - 2c^{ND}$$

i.e., iff

$$\tilde{p} \leq (\lambda - 1)v + 2c^{ND}$$

Thus, the highest price which can be charged is $(\lambda - 1)v + 2c^{ND}$ so that the highest profit associated with (D.2) is:

$$\pi^2 = (\lambda - 1)v + 2c^{ND} - c^D - F$$

Profit from Deviation (D.3): As in the case with respect to (D.1), the maximum price is $(\lambda - 1)v$. Therefore, the maximum profit from this deviation is

$$\pi^3 = 2(\lambda - 1)v - 2c^{ND} - F$$

Profit from Deviation (D.4): If a young consumer at t buys the innovation, her lifetime utility is:

(D4.1)

$$\lambda v - \bar{p} + \lambda v - c^{ND}$$

If she buys a non-durable of the old technology at their first period, her life time utility is:

(D4.2)

$$v - c^{ND} + \lambda v - c^{ND}$$

Finally, if she buys a durable of the old technology at their first period, her lifetime utility is:

(D4.3)

$$2v - c^D$$

By Assumption 1, the utility (D4.2) is greater than (D4.3). Thus, the young buys if and only if the utility from (D4.1) is greater than (D4.3), i.e.,

$$\lambda v - \bar{p} + \lambda v - c^{ND} \geq v - c^{ND} + \lambda v - c^{ND}$$

implying that

$$\bar{p} \leq \lambda v - v + c^{ND} = (\lambda - 1)v + c^{ND}$$

So, the maximum profit from (D.4) is:

$$\pi^4 = (\lambda - 1)v - F$$

Thus, the profit from deviating is $\max\{\pi^1, \pi^2, \pi^3, \pi^4\}$. Since $2c^{ND} - c^D \geq 0$, we have that $\pi^2 \geq \pi^4$. Since $c^D > c^{ND}$, we have that $\pi^3 > \pi^1$. Thus, the maximum profit from innovation is:

$$\max\{\pi^2, \pi^3\} = \max\{(\lambda - 1)v + 2c^{ND} - c^D - F, 2(\lambda - 1)v - 2c^{ND} - F\}.$$

The inequality in proposition 2 follows directly from the above equation.

Q.E.D.

5. Comparison of Efficient and Equilibrium Outcomes

Proposition 2 provides conditions which are necessary and sufficient for the persistence of stagnation. Proposition 1 provides the necessary and sufficient conditions for continuous innovation. The following proposition states that permanent stagnation is inevitable, i.e., it is the unique perfect foresight equilibrium, if the development cost is sufficiently high, while continuous innovation is inevitable if the development cost is sufficiently low. There also exists a medium range of development costs for which both outcomes are perfect foresight equilibria.

Proposition 3 (3.1) *Perpetual Stagnation is the only equilibrium if and only if*

$$F > 2(\lambda - 1)v$$

(3.2) *Continuous Innovation the only equilibrium if and only if*

$$F < \max\{(\lambda - 1)v + 2c^{ND} - c^D, 2(\lambda - 1)v - 2c^{ND}\}$$

(3.3) *Both Stagnation and Innovation are equilibria if and only if*

$$\max\{(\lambda - 1)v + 2c^{ND} - c^D, 2(\lambda - 1)v - 2c^{ND}\} \leq F \leq 2(\lambda - 1)v$$

Proof. By Assumption 1, $\max\{\bullet, \bullet\} < 2(\lambda - 1)v$. The proposition then follows directly from propositions 1 and 2. Q.E.D..

Recall that an innovation equilibrium involves the production of non-durable products, while a stagnation equilibrium involves the production of durables. Our main result is stated in the following proposition.

Proposition 4 *Suppose that $(\lambda - 1)v > 4c^{ND} - 2c^D$. Then there exists parameter values for which both stagnation and innovation are equilibrium outcomes, but the innovation equilibrium is the efficient outcome.*

Proof. From equation (1), innovation is efficient if $F < 2(\lambda - 1)v + c^D - 2c^{ND}$. The condition $(\lambda - 1)v > 4c^{ND} - 2c^D$ insures that

$$\max\{(\lambda - 1)v + 2c^{ND} - c^D, 2(\lambda - 1)v - 2c^{ND}\} < 2(\lambda - 1)v + c^D - 2c^{ND},$$

implying that such parameter values exist.

Q.E.D.

It is in this sense that planned obsolescence promotes technological advancement in our setting. This is a striking result, given our rather demanding definition of efficiency. The result would be even stronger if we ignored the first period. It is then easy to show that whenever both stagnation and innovation equilibria exist, the innovation equilibrium is efficient.

6. Conclusion

The two equilibria we identified illustrate the tradeoff between the cost efficiency associated with increased durability, on the one hand, and its inhibitive effect on further innovation, on the other hand. This paper showed that in an environment in which the innovator's advantage is short-lived, a pattern of rapidly deteriorating products and fast innovation may be superior to long-lasting products and slow innovation.

Appendix

This appendix proves that an innovation equilibrium with the production of durables does not exist. Suppose to the contrary that such an equilibrium does exist. We proceed by calculating the profit than an innovator would earn in such an equilibrium, and then show that a deviation by the innovator always yields profits that exceed those earned in equilibrium. Thus, in what follows, assume that innovators always produce durables embodying the newest technology.

We first argue that in such an equilibrium, it must be the case that only the young purchase. Suppose consumers purchase the new technology in each period. Then

the old would only be willing to pay $p = \lambda^{t-1}(\lambda - 1)v$ at the most, since they already possess a durable that will yield $\lambda^{t-1}v$ in services. In this case the innovator's profit per consumer (net of development cost) is $\lambda^{t-1}(\lambda - 1)v - c^D$. By producing a non-durable and charging the same price, per consumer profits increases to $\lambda^{t-1}(\lambda - 1)v - c^{ND}$. This shows that if an equilibrium where innovators produce durables exists, only the young buy.

Suppose that an innovation equilibrium in which durables are sold to the young only does indeed exist. Then a young consumer at t has the following options:

1. Purchase a state-of-the-art durable, and none in the second period. In this case, her utility is

$$2\lambda^t v - p^{t,D}$$

2. Purchase an outdated non-durable in each period. Her utility is

$$\lambda^{t-1}v - c^{ND} + \lambda^t v - c^{ND}.$$

3. Purchase an outdated durable, which yields a utility of

$$2\lambda^{t-1}v - c^D.$$

4. Purchase a state-of-the-art durable in each period. Her utility is

$$\lambda^t v - p^{t,D} + \lambda^{t+1}v - p^{t+1,D}.$$

Such an equilibrium exists, i.e., the young at t will choose option (1) if

$$2\lambda^t v - p^{t,D} > \max\{\lambda^{t-1}v - c^{ND} + \lambda^t v - c^{ND}, 2\lambda^{t-1}v - c^D, \lambda^t v - p^{t,D} + \lambda^{t+1}v - p^{t+1,D}\}. \quad (7)$$

By Assumption 1, option (2) is preferred to (3). Comparing the first two options, option (1) is preferred to option (2) if the innovator's price does not exceed

$$p^{t,D} = \lambda^{t-1}(\lambda - 1)v + 2c^{ND}. \quad (8)$$

Given this price, it can be verified that option (1) is preferred by the consumer to option (4). Thus, the maximum possible profit from innovating, producing a durable, and selling to the young only ($p^{t,D}$) is given by

$$\pi^{t,D} = \lambda^{t-1}(\lambda - 1)v + 2c^{ND} - c^D - F. \quad (9)$$

We now calculate the maximum (deviation) profit earned by a period t innovator from selling non-durables to both cohorts. Since the old at t already possess a durable product, the maximum price they can be charged is given by $p' = \lambda^{t-1}(\lambda - 1)v$. This true whether a durable or non-durable is sold. The (deviation) profit from producing a non-durable and selling to both cohorts is given by

$$\pi' = 2\lambda^{t-1}(\lambda - 1)v - 2c^{ND} - F. \quad (10)$$

If this profit exceeds the profit earned by producing durables and selling to the young only, then no equilibrium exists in which durable products are sold and innovation takes place in each period. From equations (9) and (10), the difference between deviation profits and equilibrium profits, $(\pi' - \pi^{t,D}) = \lambda^{t-1}(\lambda - 1)v - 4c^{ND} + c^D$. Since $\lambda^{t-1}(\lambda - 1)v$ grows over time, deviation profits will eventually exceed equilibrium profits.

Q.E.D.

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