Is Dynamic Competition Socially Beneficial? The Case of Price as Investment

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In perfectly competitive markets, prices play two related but distinct roles: allocative and distributive. In their allocative role, prices serve as incentive devices that determine consumer demand and producer supply. As such, they shape how scarce resources are allocated within and across markets, thus determining the extent of *value creation* in markets. In their distributive role, prices serve as transfers between consumers and producers, establishing levels of consumer and producer surplus, thus determining the relative amount of *value capture* by consumers and producers. Prices play these same roles in monopoly and oligopoly markets, but the distributive and allocative roles are typically in tension with each other when firms have market power. For example, a monopolist that raises its price to capture more profit will choke off units of demand that would have been socially efficient to produce, thus sacrificing value creation, leading to a deadweight loss.[1] The same tension exists in oligopoly markets, and so deadweight losses typically arise in these settings as well, though they are muted to varying degrees by the pecuniary externality that competing firms impose on each other through non-cooperative pricing or output decisions.[2]

In many interesting settings, though, there is third distinct role for prices: *the investment role*. This role arises when firms jostle for competitive advantage through the prices they set. Examples include competition for cumulative experience on a learning curve, competition to build installed base in a market with network effects, and competition to acquire customers in a market with switching costs or brand loyalty. The essential feature of these situations is that current demand translates into lower cost or higher demand in the future, which in turn implies that prices set in the current period help determine the structure of the market—the level of demand, the cost or demand positions of firms in the market, and even the number of firms—in the future. Settings in which firms jostle for advantage through pricing decisions are a feature of both "new economy" industries (e.g., Amazon versus Barnes and Noble in e-book readers) and "old economy" industries (e.g., airframes, where each new generation of aircraft entails a learning curve).

In their review of the literature on network externalities and switching costs, Farrell & Klemperer (2007) point out the implications of the investment role of prices:

> *For a firm, it [the presence of switching costs and proprietary network effects] makes market share a valuable asset, and encourages a competitive focus on af-*

[1] This presumes, of course, that the monopolust cannot engage in first-degree price discrimination.

[2] And of course, with price competition in a homogenous product market, non-cooperative behavior even with just two firms completely offsets the deadweight loss.

fecting expectations and on signing up pivotal (notably early) customers, which is reflected in strategies such as penetration pricing; competition is shifted from textbook competition in the market to a form of Schumpeterian competition for the market in which firms struggle for dominance.[3]

Given this, it would seem clear that in imperfectly competitive markets in which the investment role of prices is a significant factor, deadweight losses would be relatively low. That is, the investment role of prices would be socially beneficial (just as the allocative role of prices under perfect competition is socially beneficial). This is so for two reasons. First, as Farrell & Klemperer (2007) suggest, the investment role of prices is quite naturally associated with the use of strategies in which firms chooses lower prices than they would have chosen if they were operating in static (i.e., unchanging) world. Thus, like the pecuniary externality associated with non-cooperative pricing, the investment role of prices would be expected to result in pricing behavior that counteracts the inefficiencies due to market power.[4] Second, the investment role of prices would seem to make the structure of the market more efficient more quickly than if firms did not use price as an investment mechanism. For example, if firms set low prices to boost demand and thus enable high levels of production in the early stages of a new market, learning economies would be realized sooner rather than later.

However, there are three reasons to question this basic intuition. First, to say that the investment role of prices leads to prices that are less than static equilibrium prices does not imply that deadweight losses will be eliminated or even lessened relative to a static setting. If pricing to jostle for advantage leads to periods of time when prices are below "virtual" marginal cost—the incremental cost of producing an additional unit today, taking into account the offsetting future value from moving further down the learning curve—the deadweight loss could be greater than the traditional deadweight loss under imperfect competition.

Second, when firms use price to jostle for advantage, Besanko et al. (2014) (hereafter BDK) have shown that each competitor has both an advantage-building (AB) motive—firms choose low prices to build their own advantages (e.g., lower their own costs through learning economies)—and an advantage-denying (AD) motive—firms choose low prices to slow the pace at which rivals build their advantages and maybe even make it more likely that they exit the industry. The AB motive helps build "good" market structures faster, but the AD motive may slow the realization of "good" structures. Indeed, BDK show that the AD motive is critical in "fueling" equilibria with predation-like behavior and long-run market structures involving monopolization by a single firm. Monopolization could, of course, lead to long-run distortions due to monopoly pricing, but it could also lead to welfare losses from insufficient product variety when consumers have a high taste for variety. Concerns about market dominance have been a consistent theme of both the strategy literature (e.g., (Lieberman & Montgomery 1988)) and the industrial organization literature on settings where price can serve as an investment, as reflected in the emphasis on concepts such as increasing dominance (ID) and increasing-increasing dominance (IID) (see, for example, Cabral & Riordan (1994),

[3]Some models of non-price competition have a similar structure; see Besanko, Doraszelski & Kryukov (2014) (hereafter BDK) for a review.

[4]However, as Besanko, Doraszelski, Kryukov & Satterthwaite (2010) show (Proposition 5), there are limits to how low a price firms will charge. When a firm reaches the bottom of its learning curve and the rival firm is above the bottom of the learning curve, the leader charges a price above its marginal cost.

Budd, Harris & Vickers (1993) and Harris (1988)). Indeed, Besanko et al. (2010) have shown that market dominance, even monopolization, can arise even in the absence of ID and IID.

Third, in markets that are likely to be eventually concentrated, there are rents to be had, and we know from existing literature (Tirole 1988) that the ensuing wars of attrition can be socially costly. In dynamic models of entry and exit by homogeneous firms (Bolton & Farrell 1990), the war of attrition dynamic leads to insufficient exit (and thus socially inefficient duplication of fixed opportunity costs for some periods of time) as well as inefficient delay of entry as firms hang back not wishing to become drawn into a brutal competitive battle.[5,6] When price serves as an investment, it is conceivable that adverse entry-exit dynamics could be ameliorated, but it also conceivable that they could be made even worse. For example, below-marginal cost prices that emerge when price has an investment role, could offset the tendency for firms to stay too long—the intense competition could make the industry highly unattractive—in which case it would offset the negative welfare consequences of the war of attrition dynamic. On the other hand, it is conceivable that it could prematurely lead to exit, reinforcing the adverse impact of the appropriability effect. At the same time, the prospect of a monopoly position in an industry with fully realized demand-side economies of scale or learning economies might be so attractive that it would actually lead firms to stay longer than they would in an environment where price did not have an investment role, worsening the war of attrition dynamic. The possibility of eventual long-run dominance of the market by a single firm, coupled with an accentuated war of attrition dynamic, would imply that the actual market structure that prevails in a market equilibrium may differ from the socially efficient market structure.

On balance, then, the question of whether the investment role of prices is socially beneficial does not seem to have an "obvious" answer. The objective of this paper is to develop a framework for understanding the anatomy of the welfare impact of dynamic competition in markets in which pricing is a strategic investment for firms that jostle for competitive advantage in order to shed light on the question of whether and when this type of dynamic competition is socially beneficial. We develop our framework using a modern industry dynamics model of learning-by-doing similar in structure to Cabral & Riordan (1994), Besanko et al. (2010), and Besanko et al. (2014). Firms produce differentiated products and can achieve cost reductions through learning-by-doing. Over time, incumbent firms make pricing and exit decisions, while potential entrants make entry decisions. In our model, pricing decisions are shaped by a static motive that revolves around current profit and an investment motive, that pertains to the jostle for competitive advantage over time and is captured by the AB and AD motives. Just as competition *for* the market arises when there are switching costs and network externalities (as the quote from Farrell & Klemperer (2007) highlights), so too does it arise when there is learning-by-doing. Competition for the market is reflected by the investment role of pricing *plus* exit and entry competition, while competition *in* the market is reflected by the static part of price competition.

We develop our framework by posing two questions. First, do Markov perfect equilibria

[5]The inefficient duplication is of fixed *opportunity* costs because it takes the form not only of inefficiently high fixed "cash costs" that are incurred by firms that do not exit but also the inefficient foregoing of salvage values.

[6]Thus, unlike static models where the business stealing effect leads to too much entry, in dynamic models the business stealing effect, by fueling the war of attrition, can lead to too little entry.

(MPE) under dynamic competition in a duopoly market lead to low or high deadweight losses? Second, if dynamic competition leads to low deadweight losses, what is the mechanism by which this occurs? We address these questions in a modern industry-dynamics framework along the lines of Ericson & Pakes (1995), largely using computational analysis.

A necessary step to answer the first question is to solve the dynamic first-best problem in which a social planner chooses prices and entry and exit decisions to maximize the discounted present value of total surplus. We call this the full-control planner (FCP) problem. Under the FCP problem, the appropriability effect with respect to pricing and entry/ exit decisions is eliminated (since the planner internalizes consumer surplus as well as producer surplus); the business stealing effect with respect to pricing and entry/exit decisions is also eliminated (since the planner coordinates all pricing and entry/exit decisions); and the planner fully takes into account all dynamic effects. The solution to the FCP problem defines the first-best level of welfare which is then used to calculate deadweight losses associated with market equilibria. Specifically, the deadweight loss under a MPE is simply the difference between the discounted present value of total surplus under the first-best solution and the discounted present value of total surplus under the MPE.

Our answer to our first question is that in spite of the welfare losses due to uncoordinated exit and entry competition and static distortions arising from long-periods of below-marginal cost pricing, dynamic price competition tends to give rise to remarkably low deadweight losses. As shown in BDK, for many parameterizations there are multiple MPE. MPE with the highest deadweight losses tend to be *aggressive*—they involve predation-like pricing and eventual market dominance by a single firm. Even still, deadweight losses under these equilibria are typically less than 20 percent of the first-best total surplus. MPE with the lowest deadweight losses tend to be *accommodative*—they involve less aggressive pricing and less concentrated market structures. Deadweight losses under these equilibria are smaller than the aggressive equilibria, and in some cases are less than 1 percent.[7] When MPE are unique they are often (though not always) accommodative rather than aggressive.

To offer perspective on the magnitudes of these deadweight losses, we note that they stand in sharp contrast to the percentage deadweight losses that would arise in a counterfactual world in which we strip out both the jostling for competitive advantage—i.e., the investment roles of prices—and static price competition (only retaining dynamic exit and entry competition). This counterfactual is essentially a model of the war of attrition that underlies Posner's (1975) static model of monopoly rent seeking. This "Posner counterfactual" gives rise to deadweight losses are typically 25 to 30 percent of total surplus. The relatively low deadweight losses under dynamic price competition also stand in contrast to two other counterfactuals: one in which we strip out non-cooperative pricing but retain the investment role of pricing (thus allowing firms to collude on dynamic pricing decisions) and one in which we strip out the investment role of pricing but retain non-cooperative pricing (firms compete on price but do so myopically, not anticipating the benefits of lower costs from the learning). The latter counterfactual, which in a setting without a learning curve and product differentiation corresponds to Tirole's (1988) presentation of the war of attrition, gives rise to deadweight losses similar in magnitude to those in the "Posner (1975) counterfactual," and sometimes even greater. The former counterfactual—which can be thought of as

[7] As discussed in BDK, equilibrium selection is thus highly policy relevant.

a dynamic version of the Posner (1975) counterfactual—often entails deadweight losses that are less than those in the static Posner (1975)counterfactual but still greater—sometimes significantly so—than those under the worst MPE. A comparison of the deadweight losses under the Tirole (1988) and dynamic Posner (1975) counterfactuals suggests that while both the investment motive in pricing and non-cooperative behavior are important in making dynamic competition work as well as it does, the investment motive is typically more important than non-cooperative behavior in reducing deadweight losses.

To answer our second question, we note that the deadweight loss under a MPE can be split into two components: the difference in total surplus between the first-best and equilibrium outcomes in each possible state at each point in time (weighted by the probability of states under the equilibrium outcome and discounted and summed up over time) and the difference in the probability distributions over states between the first-best and equilibrium outcomes at each point in time (weighted by static total surplus in each state under the first-best solution and discounted and summed over time). Because the structure of the market—product variety and the cost position of each active produce—is fully identified by the states in our model, the first component identifies the *static welfare losses for given market structures*, while the second component identifies the *dynamic welfare losses from inefficient evolution of the market structure over time*. The first component can be further split into two portions: static welfare losses due to pricing distortions and static welfare losses due to the equilibrium having higher expected *net* set-up costs (set-up costs minus scrap value) than the first-best solution.[8] Thus, we decompose the deadweight loss into three terms: ($T1$) a deadweight loss due to static pricing distortions; ($T2$) a deadweight loss due to static entry/exit distortions, and ($T3$) a deadweight loss due to dynamic market structure distortions.

The low deadweight losses under competition can be attributed to four factors that operate over a wide range of parameterizations.

1. Though we do find nontrivial long-run monopoly pricing distortions in aggressive MPE (leading to high values of $T1$), in accommodative MPE these distortions are not "too large" because (a) in the short run, the MPE price path is not that different from the first-best price path and in the long run, the duopoly price distortions are not especially severe (especially when product differentiation is not particular high). Thus, $T1$ is modest under accommodative equilibria.

2. Due to the AB and AD motives, competition tends to result in very low initial prices in both aggressive and accommodative equilibria. This tends to propel a least one firm, and sometimes both firms, down the learning curve fairly rapidly, maybe even more rapidly than under the first-best outcome. Thus, for both accommodative and aggressive equilibria, there tends to be little delay in firms exploiting learning economies. In short, when we have competition, the investment role of prices is a powerful force for realizing learning economies. This tends to make $T3$ fairly low under all circumstances.

[8]The expected net set-up cost can be interpreted in one of two ways. First, it is the expected value sunk component of a firm's entry cost. Second, because the negative of the scrap value is a firm's fixed opportunity cost of remaining in the market, the expected net set-up cost is also the sum of (gross set-up) cost plus fixed opportunity costs from operation.

3. Aggressive equilibria serve a socially valuable structural purpose of identifying the single firm that will serve the entire market under circumstances that often coincide with those where the planner would also want to have the market served by a single firm. In other words, when an MPE "delivers" a monopoly market structure in the long run, it is usually the case that the planner wants a monopoly market structure in the long run as well. Though they can arise, it is much rarer to find equilibrium in which the planner would prefer to have two firms operating in the long run but the equilibrium outcome leads to monopolization. (And these cases tend to arise for empirically implausible parameter values.) Thus, under aggressive equilibria $T2$ and $T3$ both tend to be quite low.

4. Except for the smallest values of σ, there is almost always an accommodative equilibrium in which we have two firms in the long-run. But (in light of point 2), the long-run is achieved rather quickly. Now, in some cases accommodative equilibria with a long-run duopoly structure can arise for parameterizations in which the planner would prefer a monopoly (or at least put nontrivial mass on monopoly states). In these cases—which have the flavor of a unresolved war of attrition—we get insufficient exit, which tends to make the $T2$ component of the deadweight loss positive. However, this is usually offset to some degree by a negative $T3$ component (because, ex post, the structure under the accomodative equilibrium is better than the structure under the first-best solution due the gains from product variety).

All in all, though not ideal, dynamic competition when price serves an investment role works remarkably well because pricing distortions are not "too bad," it propels firms down the learning curve quickly, and it delivers the "wrong" market structure it errs on the side of too many firms, not too few. Interestingly, our finding that in a dynamic model, we tend to end up with either the same as or more than the socially optimal number of firms contrasts with findings from static models of imperfect competition with free entry. Dixit & Stiglitz (1977) and Koenker & Perry (1981) show underprovision of product variety in models with CES demand; Besanko, Perry & Spady (1990) show the underprovision of product variety for a particular specification of logit demand, while Anderson, de Palma & Thisse (1992) show underprovision of product variety under the specification of logit demand used in this paper, provided that the value of the outside good is sufficiently high.[9]

There are many examples of models in which price serves as an investment. Besides the aforementioned models of learning-by-doing, Dasgupta & Stiglitz (1988) and Cabral & Riordan (1997) also study price competition when there is learning by doing. Price also serves as an investment in the models of network effects in Mitchell & Skrzypacz (2006), Chen, Doraszelski & Harrington (2009), Dube, Hitsch & Chintagunta (2010), and Cabral (2011); habit formation in Bergemann & Välimäki (2006); and switching costs in Dube, Hitsch & Rossi (2009) and Chen (2011). However, this work has generally focused on characterizing the properties of equilibria rather than anatomizing the welfare properties of competition. Fudenberg & Tirole (1983) study the welfare properties of the subgame perfect Nash equilibrium in a two-period model with learning-by-doing, in which duopoly firms

[9]When the value of the outside good is sufficiently low, Anderson et al. (1992) show that the free-entry number of firms exceeds the socially optimal number of firms by at most 1.

choose outputs. They show that increasing the rate of learning increases welfare and that welfare could be improved by a "balanced budget" program of taxing first period output and subsidizing second-period output. However, even though it is implicit in the analysis that deadweight losses arise, it is not clear how large they are, and the paper does not undertake an analysis of why they arise. Though it does not study price as an investment explicitly, Segal & Whinston (2007) study a model in which two firms engage in Schumpeterian competition for the market. They investigate the impact on social welfare of antitrust policies that affect how an incumbent can behave toward an entrant during the period in which a new entrant has just entered the market with a new innovation that is destined, by the next period, to dislodge the incumbent (who then becomes the potential entrant the next period). They show that antitrust policy that protects new entrants and the expense of incumbents can have the salutary effect increasing the overall rate of innovation will often lead to greater incentives to innovate. The paper thus highlights that there need not be a tension between competition for the market and competition in the market. Our paper relates to Segal & Whinston (2007) in its focus on the welfare effects of dynamic competition and on teasing out the dynamic consequences of reducing sources of static welfare losses. But unlike our paper, Segal & Whinston (2007) do not explicitly model dynamic price competition (competition for the market takes the form of sequential R&D contests), nor doe they diagnose the sources of welfare losses or gains from dynamic competition.

References

Anderson, S., de Palma, A. & Thisse, J. (1992), *Discrete choice theory of product differentiation*, MIT Press, Cambridge.

Bergemann, D. & Välimäki, J. (2006), 'Dynamic price competition', *Journal of Economic Theory* **127**, 232–263.

Besanko, D., Doraszelski, U. & Kryukov, Y. (2014), 'Efficiency or predation: What drives pricing when there is learning-by-doing?', *American Economic Review* **104**(3), 868–897.

Besanko, D., Doraszelski, U., Kryukov, Y. & Satterthwaite, M. (2010), 'Learning-by-doing, organizational forgetting, and industry dynamics', *Econometrica* **78**(2), 453–508.

Besanko, D., Perry, M. & Spady, R. (1990), 'The logit model of monopolistic competition: Brand diversity', *Journal of Industrial Economics* **38**(4), 397–415.

Bolton, P. & Farrell, J. (1990), 'Decentralization, duplication, and delay', *Journal of Political Economy* **98**(4), 803–826.

Budd, C., Harris, C. & Vickers, J. (1993), 'A model of the evolution of duopoly: Does the asymmetry between firms tend to increase or decrease?', *Review of Economic Studies* **60**(3), 543–573.

Cabral, L. (2011), 'Dynamic price competition with network effects', *Review of Economic Studies* **78**, 83–111.

Cabral, L. & Riordan, M. (1994), 'The learning curve, market dominance, and predatory pricing', *Econometrica* **62**(5), 1115–1140.

Cabral, L. & Riordan, M. (1997), 'The learning curve, predation, antitrust, and welfare', *Journal of Industrial Economics* **45**(2), 155–169.

Chen, J. (2011), How do switching costs affect market concentration and prices in network industries?, Working paper, UC Irvine, Irvine.

Chen, J., Doraszelski, U. & Harrington, J. (2009), 'Avoiding market dominance: Product compatibility in markets with network effects', *Rand Journal of Economics* **49**(3), 455–485.

Dasgupta, P. & Stiglitz, J. (1988), 'Learning-by-doing, market structure and industrial and trade policies', *Oxford Economics Papers* **40**(2), 246–268.

Dixit, A. & Stiglitz, J. (1977), 'Monopolistic competition and optimum product diversity', *American Economic Review* **67**(3), 297–308.

Dube, J., Hitsch, G. & Chintagunta, P. (2010), 'Tipping and concentration in markets with indirect network effects', *Journal of Marketing Research* **29**(2), 216–249.

Dube, J., Hitsch, G. & Rossi, P. (2009), 'Do switching costs make markets less competitive?', *Journal of Marketing Research* **46**, 435–445.

Ericson, R. & Pakes, A. (1995), 'Markov-perfect industry dynamics: A framework for empirical work', *Review of Economic Studies* **62**, 53–82.

Farrell, J. & Klemperer, P. (2007), Coordination and lock-in: Competition with switching costs and network effects, *in* M. Armstrong & R. Porter, eds, 'Handbook of Industrial Organization', Vol. 3, North-Holland, Amsterdam, pp. 1967–2072.

Fudenberg, D. & Tirole, J. (1983), 'Learning-by-doing and market performance', *Bell Journal of Economics* **14**(2), 522–530.

Harris, C. (1988), Dynamic competition for market share: An undiscounted model, Working paper no. 30, Nuffield College, Oxford.

Koenker, R. & Perry, M. (1981), 'Product differentiation, monopolistic competition, and public policy', *Bell Journal of Economics* **12**, 217–231.

Lieberman, M. & Montgomery, D. (1988), 'First-mover advantages', *Strategic Management Journal* **9**, 41–58.

Mitchell, M. & Skrzypacz, A. (2006), 'Network effects and long-run market shares', *Economic Theory* **29**(3), 621–648.

Posner, R. (1975), 'The social costs of monopoly and regulation', *Journal of Political Economy* **83**(4), 807–828.

Segal, I. & Whinston, M. (2007), 'Antitrust in innovative industries', *American Economic Review* **97**(5), 1703–1730.

Tirole, J. (1988), *The theory of industrial organization*, MIT Press, Cambridge.