Cumulative Innovation and Competition Policy

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Abstract. We develop a stylized model of a Schumpeterian industry, characterized by cumulative innovation and a succession of incumbent monopolists, to address issues in competition policy toward abuse of dominance. Incumbents' R&D investments increase future social surplus flows as well as the incumbents' tenure in the market, thus generating both positive and negative intertemporal externalities. We find that conduct that appropriates surplus ("extraction") increases innovation and surplus growth. By contrast, conduct that lengthens incumbent tenure ("extension") increases innovation and surplus growth when the net intertemporal externality is positive but decreases innovation and surplus growth when the net intertemporal externality is negative.

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1 Introduction

Competition policy toward abuse of dominance has been much discussed in recent years by economists and competition authorities on both sides of the Atlantic.[1] The central issues have potentially far reaching implications for innovation and growth. Exclusionary abuse, conduct that artificially extends monopoly power, is prohibited in both the European Union and United States. The exploitation of monopoly power, on the other hand, appears to be accorded very different treatment across the two jurisdictions, at least in principle. Article 102(a) of the Treaty on the Functioning of the EU prohibits a dominant firm from "imposing unfair purchase or selling prices."[2] In the US, by contrast, Section 2 of the Sherman Act (15 U.S.C. § 2) prohibits monopolization, which involves exclusionary conduct, but not monopoly pricing.[3]

We contribute to this discussion by analyzing whether the *extension* of monopoly power has qualitatively different effects on innovation and growth from the *exploitation* of such power. Many economists have informally expressed the view that competition policy should be more permissive toward exploitation than extension.[4] The topic has not

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[1] The European Commission (EC) initiated a lengthy review of its policies regarding abuse of dominance in 2003, culminating in 2009 with the EC's issuance of guidance on its enforcement priorities regarding exclusionary abuse. In the US, the Department of Justice (DOJ) and Federal Trade Commission (FTC) jointly initiated in 2006 a series of public hearings on single-firm conduct. At the conclusion of these hearings, the DOJ issued its findings in 2008, in a report in which the FTC pointedly did not join. With the change in administrations in 2009, the DOJ withdrew the report. Both the EC and US antitrust agencies have grappled with the issue of how to most effectively identify harmful exclusionary conduct.

[2] See Vickers (2005). Before the recent renumbering, Article 102 was Article 82.

[3] As Areeda, Kaplow and Edlin (2004) observe, "courts and commentators are in uncommon accord that monopolization entails something more than monopoly. Monopolization requires exclusionary conduct."

[4] Carlton and Heyer (2008) argue that the two types of conduct should be treated differently in US law on the basis that extension (but not exploitation) can cause harm by weakening the competitive constraints facing a firm. Motta and de Streel (2007) and others have argued that EU Article 102's prohibition on exploitative abuse should be applied only narrowly, where entry barriers are both high and durable, so as not to weaken investment incentives.

previously been subject to rigorous formal analysis, however, despite its clear relevance to the antitrust policy debate. We aim to take first steps in such an analysis.

To this end, we explore a stylized model of single-firm conduct in a Schumpeterian industry in which innovation is sequential and leads to a succession of incumbent monopolists. Each monopolist selects the quality of its innovation and is eventually displaced by a firm (the next monopolist) drawn from a pool of symmetric potential entrants. A higher quality innovation increases surplus flows and also lengthens the monopolist's tenure. Two intertemporal externalities emerge immediately. First, firms *stand on the shoulders of giants*: current innovation raises surplus flows not just in the current incumbency but in all future incumbencies. Second, firms *beggar their successors*: current innovation tends to slow surplus growth by lengthening incumbent tenure and thereby delaying the realization of future innovation.[5] The net intertemporal externality of innovation can be positive or negative, and its sign plays a critical role in our analysis.

In this setting, we examine the effects of conduct that enables the incumbent to appropriate social surplus ("monopoly extraction") and conduct that lengthens incumbent tenure ("monopoly extension") on innovation and welfare. We find that, in steady-state equilibrium, both the magnitude of periodic innovation and the average growth rate in surplus increase with monopoly extraction. Our analysis thus lends some support to the view that applying the category of exploitative abuse to Schumpeterian industries could

[5] The first of these externalities plays a central role in the sequential innovation literature and in discussions of patent policy (e.g., Scotchmer, 1991; Green and Scotchmer, 1995; O'Donoghue, 1998; O'Donoghue, Scotchmer and Thisse, 1998). The second externality receives less emphasis in this literature, with some exceptions (e.g., Denicolo, 2000).

jeopardize innovation and growth.[6] We further find that the qualitative effects of monopoly extension depend on the sign of the net intertemporal externality of innovation. In particular, monopoly extension increases the magnitude of periodic innovation and the average growth rate in surplus when the net externality is positive but decreases innovation and growth when the net externality is negative.

The latter result begs the question of how the sign of the net intertemporal externality of innovation might be ascertained in practice. We find, however, that changes in incumbent innovation proxy welfare changes from the associated conduct, given a plausible assumption on innovation effects (condition (23) or (28) below). This suggests a policy rule of thumb: conduct suspected to be exclusionary abuse is more likely to harm welfare when associated with a reduction in the incumbent's innovation; when such conduct is associated with a genuine advance in innovation by the incumbent it is more likely to have salutary effects. This rule of thumb is similar to a "sham" test for innovation proposed by Gilbert (2007). Our results suggest that a more restrictive test for "predatory innovation," along the lines of Ordover and Willig (1982), would tend to chill innovation and slow growth in surplus, again given a plausible assumption on innovation effects.

The paper closest to ours is that of Segal and Whinston (2007), which examines the interplay of innovation and antitrust policy and whose modeling likewise takes its inspiration from Schumpeterian growth theory (e.g., Grossman and Helpman, 1991;

[6] This view appears consistent with past EU rulings. Wahl (2007), a judge at the Court of First Instance, states that "the Court has not yet condemned a particular pricing practice, in a *free and unregulated market*, as amounting to unfairly high and exploitative prices and thus constituting an infringement of Article 82" (emphasis added). Cf. Werden (2009) for further discussion.

Aghion and Howitt, 1992).[7] We depart from the approach in these papers, however, in that we focus on incumbent R&D choices rather than those of potential entrants. Competition issues regarding dominant firms commonly involve conduct that is closely linked with a purported innovation by the dominant firm. Our primary interest is to understand the consequences of single-firm conduct in such settings. Traditional Schumpeterian models are less well suited to this goal, given that the incumbent monopolist typically undertakes no R&D in such models (likewise in Segal and Whinston, 2007) due to Arrow's (1962) replacement effect.

In a more recent thread of research on Schumpeterian growth theory, an escape-competition effect (or escape-entry effect) can spur the incumbent to innovate so as to gain technological distance from actual or potential rivals (Aghion et al, 2001; Howitt and Mayer-Foulkes, 2005; Acemoglu, Aghion and Zilibotti, 2006).[8] A key feature of our model, that monopoly tenure tends to increase with the quality of the incumbent's innovation,[9] is consistent with this research.[10] We initially assume that only the

[7] Aghion and Howitt (2006) provide a synthesis of the literature on Schumpeterian growth theory. Vickers (2010) analyzes the conditions under which antitrust authorities should require an incumbent monopolist to share intellectual properties with its competitors; the discussion can be related to our results regarding monopoly extension.

[8] See Aghion et al (2009) for supportive empirical evidence. Gilbert and Newbery (1982) first identified an escape-competition effect spurring incumbent R&D. See also Etro (2004) for an alternative explanation, based on first-mover commitment power, for why the incumbent may undertake R&D more intensely than potential entrants.

[9] We diverge from much existing literature on endogenous growth in that we treat R&D as affecting both the frequency and quality of innovation. Quality-ladders models tend to focus on innovation frequency to the exclusion of innovation quality. Akcigit (2009) calls attention to the importance of redressing this imbalance with empirical evidence that variation in the quality of innovations is substantial. Our approach can be interpreted as an initial foray into generating results when both the quality and frequency of innovation vary endogenously.

[10] Although the literature identifies distance to the technological frontier (or "neck and neckness") as a key determinant of innovation incentives, measuring this distance could prove problematic for competition authorities. We do not explicitly model such underlying factors that influence incumbent innovation.

incumbent monopolist undertakes R&D,[11] but later (in Section 4.3) discuss how our results continue to hold qualitatively when this assumption is relaxed so that potential entrants also invest, in settings where incumbent and potential entrant R&D are (implicitly) strategic substitutes and reaction functions slope downwards.

The remainder of the paper is organized as follows. We lay out the economic environment in Section 2. In Section 3, we derive the privately optimal level of monopoly innovation, develop the two countervailing intertemporal externalities, discuss monopoly extraction and monopoly extension, and show how innovation incentives are affected by each. Then, in Section 4, we introduce two concepts of the social optimum and show how they are affected by extraction and extension. We discuss possible implications for competition policy in Section 5, and conclude in Section 6.

2 Economic Setting

A period in our model represents the lifespan of a given incumbent monopolist. At the outset of each period t, a new incumbent is drawn from a pool of symmetric potential entrants; we refer to the firm operating in period t as firm t. Firm 1 is incumbent for some span of time τ_1. Period 2 commences at τ_1, at which point firm 2

[11] Although our intent is to simplify exposition, industries that conform to this assumption may be surprisingly common. Consider Bill Gates's (1995) description of Microsoft's beginnings:

> "We were in the right place at the right time. We got there first, and our early success gave us the chance to hire more and more smart people."

Other "new economy" firms likewise gained leadership positions through serendipity, undertaking most of their R&D only after having established themselves. Chad Hurley, a founder of YouTube, has said:

> "Whether it's [Google founders] Larry [Page] or Sergey [Brin] or other people like [Facebook co-founder] Mark Zuckerberg ... We're all coming from these simple ideas. We were all really lucky to be in the right place at the right time." (Gibson, 2008)

becomes the incumbent and remains so for some span τ_2. Firm 3 becomes the incumbent at time $\tau_1 + \tau_2$, and so on. Figure 1 depicts the game timeline for arbitrary values of τ_t.

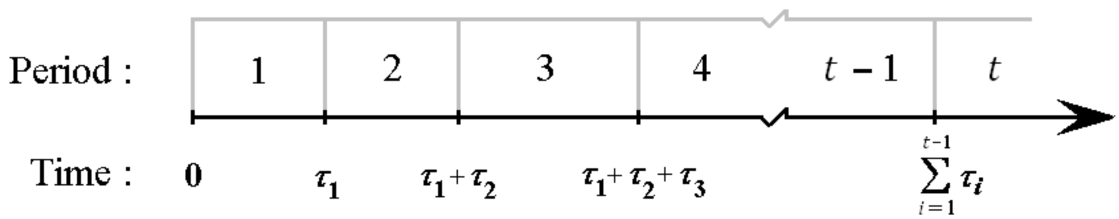

Figure 1. Incumbency Timeline

The length of period t (lifespan of firm t) is given by

$$\tau_t = \phi(y_t)\ , \tag{1}$$

where $y_t \geq 0$ is the magnitude of the innovation chosen by firm t (and undertaken at the outset of period t). The incumbent tenure function has the properties $\phi(0) > 0$ and $\phi' > 0$. Incumbent tenure thus increases with innovation, capturing the idea that a firm's technological leadership and resulting dominance is more durable the more innovative the firm strives to be.[12]

Innovation y_t also increases the flow rate of gross surplus S_t. This is surplus gross of both monopoly deadweight losses and R&D costs, as discussed more fully below. We assume the flow rate of gross surplus is constant within each period but increases (weakly) from period to period, evolving according to $S_t = (1 + y_t)\, S_{t-1}$, with the exogenously given base flow rate in period 1 denoted by S_0.

[12] For concreteness, one might think of potential entrants in our setting as receiving a stream of private ideas, as in O'Donoghue et al (1998). Upon getting a sufficiently good idea, an entrant displaces the incumbent, but this takes longer the greater the incumbent's innovation. See also Aghion et al, 2001, Howitt and Mayer-Foulkes, 2005, and Acemoglu, Aghion and Zilibotti, 2006.

We take monopoly deadweight losses to be a fixed proportion δ of S_t, $\delta \in [0,1)$. Surplus flows net of deadweight losses are given by $s_t = (1-\delta)\, S_t$ and we adopt the normalization $S_0 = 1/(1-\delta)$ so that $s_0 = 1$. Surplus flows net of deadweight losses thus evolve according to

$$s_t = (1 + y_t)\, s_{t-1}\,, \tag{2}$$

so that $s_t = \prod_{i=1}^{t}(1 + y_i)$. Note that our analysis abstracts from changes in δ arising from investment-induced changes in underlying market demand or cost.[13]

Taking equation (1) into account, the present value of the stream s_t that is realized within period t, evaluated as of the beginning of the period, can be written as

$$\int_0^{\phi(y_t)} s_t\, e^{-rx}\, dx \;=\; \tfrac{1}{r}\left(1 - e^{-r\,\phi(y_t)}\right)(1 + y_t)\, s_{t-1}, \tag{3}$$

where $r > 0$ is a discount rate common to all firms / periods. This is the gross social benefit (gross of R&D costs) of y_t that is realized within period t. It can be decomposed as the product of two factors, s_{t-1}, which is the surplus flow firm t inherits from her immediate predecessor, and $b(y_t)$, which is firm t's contribution to gross social benefit:

$$b(y_t) \equiv \tfrac{1}{r}(1 + y_t)\left(1 - e^{-r\,\phi(y_t)}\right). \tag{4}$$

Firm t's contribution to gross social benefit realized within period t can be further decomposed as the product of $\tfrac{1}{r}(1 + y_t)$ and $1 - e^{-r\,\phi(y_t)}$ on the RHS of (3). Innovation y_t increases surplus flows not only within period t but in all future periods as well. The overall present value of this stream of social benefits is proportional to $\tfrac{1}{r}(1 + y_t)$, but

[13] Suppose demand and marginal cost are both linear, tracing out a triangle of area S_t. With linear pricing, the deadweight loss triangle has area δS_t. If y_t shifts demand (upward) or cost (downward) in parallel relative to period $t-1$, then δ does not change. This is true for a broader range of investment effects so long as the relevant areas scale up similarly and also for nonlinear pricing so long as the "efficiency of the extraction technology" remains unchanged.

only the fraction $1 - e^{-r\,\phi(y_t)}$ of the stream is realized within period t (and so is potentially appropriable by firm t).

The monopolist captures the portion $\mu \in [0, 1]$ of the surplus flow s_t, the rest being retained by consumers. In keeping with the terminology of Carlton and Heyer (2008), we refer to μ as the rate of monopoly "extraction," which we assume is common to all incumbents and periods. We do not model the extraction process, but rather treat μ as an exogenous parameter, one that is potentially influenced or determined by competition policy.[14] We interpret increases in μ as improvements in the monopolist's ability to extract surplus through more flexible forms of pricing. In addition to our simplifying assumption that the deadweight loss parameter δ is constant across periods, we further assume that δ is invariant to changes in μ. We thus set aside any static welfare effects of price discrimination to highlight its potential dynamic impact through changed investment incentives.

The R&D cost of innovation y_t, incurred at the beginning of period t, is

$$k_t(y_t) = c(y_t)\, s_{t-1}\,, \tag{5}$$

where $c(0) = c'(0) = 0$ and for $y_t > 0$, $c', c'' > 0$. Innovation by earlier firms thus makes later innovation more difficult. This is consistent with evidence that patents per researcher have declined substantially over time in many countries (Kortum, 1997).

Although the R&D costs of innovation grow with time in the model, so too do the associated rewards. Our assumed balancing of these effects (compare equations (2) and (5)) simplifies the analysis considerably by yielding a steady-state equilibrium rate of

[14] In particular, we assume μ is invariant to innovation. Though innovation might facilitate extraction by softening competition with rival (outside) goods, we set this possibility aside in our monopoly setting to highlight the intertemporal effects of investment through its impact on monopoly tenure, $\phi(\cdot)$.

innovation and average growth. It is also consistent with the empirical evidence on "growth without scale effects" (Jones, 1995a,b), as well as modeling approaches taken in the "second wave" of endogenous growth theories (e.g., Aghion et al., 2001; Howitt, 1999; Jones, 1995b; Kortum, 1997; Segerstrom, 1998).

3 The Private Optimum

Firm t's profit is the difference between the present value of innovation benefits appropriated by the firm and the associated R&D costs:

$$\Pi_t = \big(\mu\, b(y_t) - c(y_t)\big)\, s_{t-1} \equiv\ \pi(y_t)\, s_{t-1}\,. \tag{6}$$

The private optimum y^* is implicitly defined by the first-order condition

$$\mu\, b'(y) - c'(y) = 0. \tag{7}$$

We further assume that profit is concave,

$$\mu\, b''(y) - c''(y) < 0\,, \tag{8}$$

to ensure the optimum is unique.

Lemma 1. *The privately optimal innovation choice is stationary.*

Proof: By inspection of equation (6), firm t's optimum does not depend on s_{t-1}. □

Given stationarity, we drop subscripts t hereafter.

3.1 Intertemporal Externalities of Innovation

Differentiating equation (4) yields

$$b'(y) = \tfrac{1}{r}\left\{1 - e^{-r\,\phi(y)}[1-(1+y)\,r\,\phi'(y)]\right\}\ > 0.^{15} \tag{9}$$

[15] One can more readily see $b'(y) > 0$ by rewriting equation (9) as $b'(y) = \frac{1}{r}\left(1 - e^{-r\,\phi(y)}\right) + (1+y)\,\phi'(y)\,e^{-r\,\phi(y)}$.

This is the within-period marginal social benefit of innovation.[16] Of especial interest is the expression within square brackets,

$$1 - (1 + y)\, r\, \phi'(y)\ , \tag{10}$$

which represents the *intertemporal externality of innovation*. Evaluating the sign of expression (10) is central to our main results on innovation and welfare.

Definition. *Innovation has a positive (negative) intertemporal externality at innovation level y if and only if* $1 - (1 + y)\, r\, \phi'(y) > 0\ (< 0)$.

Observe that if incumbent innovation were to have no effect on incumbent tenure, i.e., $\phi'(\cdot) = 0$, expression (10) would simplify to 1 and equation (9) would become $b'(y) = \frac{1}{r}\left(1 - e^{-r\,\phi(y)}\right)$. In this case, current-period innovation would have a *positive* intertemporal externality: only the fraction $1 - e^{-r\,\phi(y)}$ of the marginal social benefit of innovation would be realized in the current period and so be potentially appropriable by the innovator. Insofar as innovation tends to lengthen tenure, $\phi'(\cdot) > 0$, expression (10) falls below one and this incumbency effect of innovation helps to internalize the positive intertemporal externality (so long as expression (10) remains nonnegative).

When expression (10) falls zero, equation (9) becomes $b'(y) = \frac{1}{r}$. The intertemporal externality then disappears: the full marginal social benefit of innovation is captured within the current period. The reason is that in this case two countervailing intertemporal effects of innovation are in equipoise. A positive spillover from innovation is that later innovators *stand on the shoulders of giants*: current-period innovation boosts the flow of gross surplus in all future periods. The shoulders-of-giants effect pushes innovators toward underinvestment. A negative spillover is the business-stealing effect

[16] When multiplied by s_{t-1} for firm t.

that innovators *beggar their successors*: current-period innovation, by lengthening the incumbent's tenure, delays the realization of all future innovations. This pushes innovators toward overinvestment. When expression (10) is zero these effects exactly cancel and each incumbent fully internalizes the intertemporal externalities of innovation.

Finally, when expression (10) turns negative, $b'(y) > \frac{1}{r}$. In this case, the beggar-thy-successor effect dominates the shoulders-of-giants effect, giving incumbents an excessive incentive to innovate from a social, intertemporal perspective.

3.2 Monopoly Extraction and Innovation

A second, within-period externality arises when firms fail to fully capture the social benefits of innovation that flow during their tenure in the market, i.e., when $\mu < 1$.

Proposition 1. *Steady-state equilibrium innovation increases with monopoly extraction.*

Proof: Differentiating the first-order condition (7) with respect to μ yields

$$\frac{\partial y^*}{\partial \mu} = \frac{-\,b'}{\mu b'' - c''}\ , \tag{11}$$

which is positive by conditions (8) and (9). □

Hereafter, let $y^*(\mu)$ denote steady-state equilibrium innovation for a given monopoly extraction rate μ. Clearly $y^*(0) = 0$, and we assume $y^*(1)$ is finite.

3.3 Monopoly Extension and Innovation

We now decompose incumbent tenure as

$$\phi(y) = \lambda(y) + \varepsilon\ , \tag{12}$$

where ε is an additive "monopoly extension" parameter.

Proposition 2. *Steady-state equilibrium innovation increases (decreases) with monopoly extension if the intertemporal externality is positive (negative).*

Proof: Differentiating the first-order condition (7) with respect to the monopoly extension parameter ε yields

$$\frac{\partial y^*}{\partial \varepsilon} = \left(\frac{-\mu}{\mu b'' - c''}\right) \frac{\partial b'}{\partial \varepsilon} \tag{13}$$

by the implicit function theorem. The expression in parentheses is positive by condition (8) and thus $\partial y^*/\partial \varepsilon$ has the same sign as $\partial b'/\partial \varepsilon$. Differentiating equation (9) with respect to ε, taking equation (12) into account, then yields

$$\frac{\partial b'}{\partial \varepsilon} = [1 - (1 + y) r\, \phi'(y)]\, e^{-r\,\phi(y)}. \tag{14}$$

Given that the bracketed expression in equation (14) is expression (10), $\partial y^*/\partial \varepsilon$ has the same sign as the intertemporal externality of innovation. □

Intuitively, monopoly extension helps to internalize the intertemporal externality, spurring innovation if the externality is positive and paring it back if the externality is negative. This does not necessarily imply, however, that monopoly extension improves welfare, as we show in the next section.

4 The Social Optimum

We consider two measures of welfare. One is the present value of the stream of net surplus. This measure is finite, however, only when growth in surplus in the industry is not too rapid relative to discount rates. Yet competition issues often arise precisely in industries where innovation is most rapid. As an alternative welfare metric, we also consider the average growth rate in surplus.

For a given steady-state innovation y, the present value of the stream of surplus (net of periodic R&D costs), evaluated at the start of the game ($t = 0$), can be written as

$$W(y) = w(y)X(y)\ , \tag{15}$$

where $w(y)$ is the component of periodic welfare that is common across periods,

$$w(y) \equiv b(y) - c(y)\ , \tag{16}$$

and

$$X(y) \equiv \sum_{t=1}^{\infty} \left[(1+y)e^{-r\,\phi(y)}\right]^{t-1} \tag{17}$$

is a scaling factor. If

$$(1 + y^*(\mu))\ e^{-r\,\phi(y^*(\mu))} < 1 \tag{18}$$

for all $\mu \in [0,1)$, the series in equation (17) always converges. In this case the scaling factor $X(y^*(\mu))$ and present value of welfare $W(y^*(\mu))$ are finite. But if surplus growth is rapid and discounting low, condition (18) does not hold and the series in (17) diverges.

We also consider the average growth rate in surplus as a welfare measure independent of discount rates. Given innovation y realized every period, the flow of net surplus in a given period t, expressed as a present value as of the beginning of the period, is $w(y)(1+y)^t$. The time elapsed from the beginning of the game to the end of period t is $t\ \phi(y)$. We refer to the ratio of these as *the welfare growth rate through period* t:

$$R_t(y) \equiv \frac{w(y)(1+y)^t}{t\ \phi(y)}\,. \tag{19}$$

We first derive results on welfare growth rates, then show that analogous results hold for the present value of welfare.

4.1 Monopoly Extraction, Extension and Welfare Growth

The first derivative of the welfare growth rate through period t can be written as

$$R_t{}'(y) = \tfrac{1}{y} R_t(y)\ \left(\eta_{w,y} - \eta_{\phi,y} + \left(\tfrac{y}{1+y}\right) t\right), \tag{20}$$

where

$$\eta_{w,y} \equiv \frac{y\,w'(y)}{w(y)} \tag{21}$$

is the elasticity of the periodic welfare component $w(y)$ with respect to y and

$$\eta_{\phi,y} \equiv \frac{y\,\phi'(y)}{\phi(y)} \tag{22}$$

is the elasticity of incumbent tenure $\phi(y)$ with respect to y.

Lemma 2. *Greater steady-state equilibrium innovation implies higher welfare growth through every period if*

$$\eta_{w,y} \geq \eta_{\phi,y}\ . \tag{23}$$

Proof: Follows by inspection of equation (20). □

Given that the magnitude and frequency of innovation tend to move in opposite directions in our comparative statics, the net effect of innovation on welfare growth is ambiguous. Lemma 2 states, however, that if the periodic component of welfare $w(y)$ is at least as elastic with respect to innovation as is incumbent tenure $\phi(y)$, then innovation spurs welfare growth on net. Note that (23) is a strongly sufficient condition for innovation to spur welfare growth. Arguably, condition (23) is consistent with a common understanding of what constitutes an "innovation."[17] If condition (23) were sharply violated, the activity in question would begin to look more like naked monopoly extension (or exclusionary abuse of dominance) than genuine innovation.

Proposition 3. *Assume condition (23) holds*.

(a) *Monopoly extraction raises welfare growth through every period.*

[17] Lemma 2 has a similar flavor to O'Donoghue's (1998) result that a patentability requirement (a minimum innovation size required to obtain patent protection) can improve dynamic efficiency.

(b) *Monopoly extension raises (lowers) welfare growth through every period if the net intertemporal externality is positive (negative).*

Proof: Given Lemma 2, part (a) follows from Proposition 1 and part (b) follows from Proposition 2. □

4.2 Monopoly Extraction, Extension and PV Welfare

Differentiating (17) yields

$$X'(y) = [1 - (1+y)\, r\, \phi'(y)]\, e^{-r\,\phi(y)} \sum_{t=2}^{\infty} (t-1)\left[(1+y)e^{-r\,\phi(y)}\right]^{t-2}. \qquad (24)$$

The intertemporal externality of innovation is captured in $X'(y)$:

Lemma 3. *Assume condition (18) holds, so that $X(y)$ is finite. $X'(y)$ has the same sign as the intertemporal externality.*

Proof: By inspection of equation (24), $X'(y)$ and expression (10) have the same sign. □

From equation (15), the derivative of the present value of welfare with respect to innovation is

$$W'(y) = w'(y)X(y) + w(y)X'(y). \qquad (25)$$

The term $w'(y)X(y)$ in equation (25) reflects within-period effects of innovation on the present value of welfare, whereas the term $w(y)X'(y)$ reflects intertemporal effects. In the absence of an intertemporal externality (i.e., for $X'(y) = 0$), innovation has only within-period effects, in which case $W'(y)$ necessarily has the same sign as $w'(y)$. Otherwise, innovation also affects the present value of welfare through the intertemporal component $w(y)X'(y)$, which tends to raise $W(y)$ when the intertemporal externality is positive and lower it when the externality is negative.

Equation (25) can be written as

$$W'(y) = \frac{1}{y}\left(\eta_{w,y} + \eta_{X,y}\right), \tag{26}$$

where

$$\eta_{X,y} \equiv \frac{y\,X'(y)}{X(y)} \tag{27}$$

is the elasticity of the scaling factor $X(y)$ with respect to y.

Lemma 4. *Assume condition (18) holds. Greater steady-state equilibrium innovation implies a larger present value of welfare if and only if*

$$\eta_{w,y} > -\,\eta_{X,y}\;. \tag{28}$$

Proof: Follows by inspection of equation (26). □

Lemma 4 is analogous to Lemma 2; it specifies a necessary and sufficient condition for innovation to raise welfare in present value terms. Given that $\eta_{w,y} > 0$ in steady state equilibrium, condition (28) certainly holds when the intertemporal externality is positive, in which case $X'(y) > 0$ by Lemma 3 and thus $\eta_{X,y} > 0$. Condition (28) further requires that the intertemporal externality not be too strongly negative. The term $\eta_{X,y}$ in condition (28) is closely related to the incumbent tenure elasticity $\eta_{\phi,y}$ in condition (23). By equation (24), $\eta_{X,y}$ is smaller the larger is $\phi'(y)$, turning negative and leading to violation of condition (28) for $\phi'(y)$ sufficiently large.

Proposition 4. *Assume conditions (18) and (28) both hold.*

(a) *Monopoly extraction raises the present value of welfare.*

(b) *Monopoly extension raises (lowers) the present value of welfare if the intertemporal externality is positive (negative).*

Proof: Given Lemma 4, part (a) follows from Proposition 1 and part (b) follows from Proposition 2. □

4.3 Active Potential Entrants

Results analogous to Propositions 3 and 4 hold if we relax our assumption that potential entrants do not invest at all. Let $K(y)$ denote aggregate R&D investment by potential entrants as a function of the incumbent's innovation choice y, with $K(y) > 0$ and also $K'(y) < 0$, reflecting downward-sloping reaction functions. Assume that a unique and interior steady-state equilibrium exists, and that surplus net of all costs (including potential entrant R&D) is positive and grows from period to period in this equilibrium. We can define a new measure of periodic welfare as $u(y) \equiv w(y) - K(y)$, a new measure of the present value of welfare as $U(y) \equiv u(y)X(y)$, and a new measure of the average growth rate in surplus as $\rho_t(y) \equiv \frac{u(y)(1+y)^t}{t\,\phi(y)}$. The developments in Section 4.1 and 4.2 continue to hold, *mutatis mutandis*, by everywhere replacing $w(y)$ with $u(y)$.

5 Discussion

On the foregoing analysis, monopoly extraction and monopoly extension have distinct effects, and the distinctions turn on the sign of the intertemporal externality of innovation. Extraction and extension tend to have similar effects on innovation and welfare when the intertemporal externality is positive. Their effects can diverge sharply, however, when the intertemporal externality is negative. Monopoly extension inhibits innovation and adversely affects welfare when the intertemporal externality is negative, whereas monopoly extraction tends to promote both innovation and welfare regardless of the sign of the externality.

Insofar as innovation and growth are important considerations in the fashioning of competition policy, the analysis suggests a rationale for broadly permitting monopoly extraction in Schumpeterian industries but prohibiting monopoly extension if the intertemporal externality of innovation is negative. This begs the question, however, of how the sign of the externality might be determined. A related and equally thorny question is how monopolization or exclusionary abuse might be distinguished in practice from innovative activity that extends monopoly tenure through competition on the merits.

The analysis in Section 3 suggests an answer of sorts to both quandaries. Recall that monopoly extension induces the incumbent to either expand R&D and innovation, when the intertemporal externality is positive, or to pare both back when the externality is negative. In the former case, the activity in question typically improves welfare, but in the latter case the activity typically harms welfare. This suggests a policy rule of thumb: conduct suspected to be exclusionary abuse is more likely to harm welfare when associated with a reduction in the incumbent's innovation; when such conduct is associated with a genuine advance in innovation by the incumbent it is more likely to have salutary effects. Determining what constitutes a genuine "innovation" by a monopolist or dominant firm may pose hard challenges for competition authorities, but the task is far less complex than measuring welfare changes or evaluating the sign of the intertemporal externality directly.

This rule of thumb is similar to a "sham" test for innovation discussed by Gilbert (2007). Such a test would not involve weighing the potential benefits of an innovation against possible adverse consequences, but simply a judgment as to whether the innovation is genuine or a sham. Our main results (Propositions 3 and 4) both require restrictions (conditions (23) and (28), respectively) that could be interpreted as consistent with a sham test. We do not suggest that either condition (23) or (28) offers a realistic basis for an administrable rule in competition policy. Rather, we interpret these conditions as being broadly consistent with a common understanding of what constitutes a genuine innovation, and so we interpret Propositions 3 and 4 as applying to genuine innovations.

Much stricter than a sham test would be a test for “predatory innovation,” as developed by Ordover and Willig (1982).[18] In such a test, an innovation would be found predatory if the innovation is unprofitable but for its exclusionary effects. Note, however, that in the steady-state equilibrium of our model innovation is predatory (in this sense) at the margin, because the privately optimal innovation choice incorporates innovation’s effect of extending incumbent tenure. This suggests that enforcing a prohibition on exclusionary abuse using a predatory innovation test could have a chilling effect, leading incumbents to innovate less and thus tending to harm welfare by Propositions 3 and 4.

6 Conclusions

We have developed a stylized model of a Schumpeterian industry to explore issues in competition policy toward abuse of dominance. In particular, we consider whether the extension of monopoly power has qualitatively different effects on innovation and growth from the exploitation of monopoly power. Our results suggest that both the magnitude of innovation and the average growth rate in surplus increase with the ability of monopolists to extract social surplus. By contrast, monopoly extension has ambiguous effects that hinge on the net intertemporal externality of innovation: extension increases innovation and growth when this net externality is positive but decreases innovation and growth when it is negative. Our analysis suggests a rule of thumb that single-firm conduct which extends incumbents’ tenure increases surplus growth when it

[18] Ordover and Willig (1982) discuss “predatory product innovation,” but an analogous approach could be taken with respect to “predatory process innovation.”

is associated with genuine advance in innovation. Given that innovation is likely more visible to competition authorities and courts than are changes in welfare growth rates, this rule of thumb may have practical value.

Our theoretical results offer a rationale for basic features of US and EU antitrust enforcement regarding single-firm conduct. In the US, Section 2 of the Sherman Act prohibits monopolization but not monopoly pricing,[19] and there is broad consensus among courts and legal scholars that single-firm conduct must be exclusionary to be condemned. In the EU, however, Article 102(a) of the TFEU appears generally to prohibit purely exploitative abuse of dominance as well. Yet "all but a few EC cases on abuse of dominance have concerned exclusionary conduct by dominant firms…rather than behaviour directly exploitative of consumers" (Vickers, 2005), and the prohibition on exploitative abuse has been applied narrowly (Wahl, 2007). Our analysis suggests that this focus on exclusionary abuse and limited application of exploitative abuse is appropriate, insofar as innovation and growth are important considerations in the fashioning of competition policy.

Our analysis, like that of Segal and Whinston (2007), illustrates how insights into the effects of single-firm conduct can be obtained from stylized models that follow in the tradition of Schumpeterian growth theory. We believe further research along these lines offers great potential. With regard to our own analysis, two extensions might prove promising. First, one could investigate implications of single-firm conduct when there is a trade-off between static efficiency and the rewards to innovation. This trade-off is

[19] In *US v. Alcoa*, 148 F.2d 416, 430 (2d Cir. 1945), Judge Learned Hand opined: "the successful competitor, having been urged to compete, must not be turned upon when he wins." Nonetheless, US courts have sometimes treated single-firm conduct as exclusionary when an economist might consider the conduct to be purely exploitative. See the critique in Carlton and Heyer (2008).

prominent in the sequential innovation literature relating to patent policy (e.g., Green and Scotchmer, 1995; O'Donoghue, 1998). We have abstracted from this issue, setting aside any static welfare effects of price discrimination to highlight its potential dynamic impact through changed investment incentives. Second, our focus on welfare rather than consumer surplus is debatable from an antitrust perspective. It is important to note that our results on welfare growth rates extend immediately to consumer surplus growth rates, given that consumer surplus is a fixed fraction of welfare. The effects of single-firm conduct on the present value of consumer surplus are subtler, however, and may warrant further study.

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