Supplemental Materials for John H. Nachbar, Bruce C. Petersen and Inhak Hwang, "Sunk Costs, Accommodation, and the Welfare Effects of Entry," *The Journal of Industrial Economics* 46(3), September 1998, pp. 317-332

A Single Entrant. *Monopoly Capacity* Scenario.

Recall that under the *monopoly capacity* scenario, the incumbent has the monopoly level of capacity in place at the time of entry. We consider an alternative, in which the incumbent chooses capacity strategically, in the next section.

A.1 $s > 0$ and $F = 0$

Let ΔSW denote the change in social welfare, normalized by dividing by monopoly social welfare. The general expressions for ΔSW when $s > 0$ and $F = 0$ are as follows.

If $s \geq \frac{1}{2}(a-c) - 2\lambda c$ (region B^s in Figure 3 in the paper), so that the incumbent does not accommodate, ΔSW is the sum of two terms. The first term gives the gain in social welfare that would occur if production were allocated efficiently; since $s > 0$, efficient production means that only the incumbent produces. This gain stems from increased consumer surplus as a result of higher industry output. The second term, which is smaller in absolute value than the first, subtracts off the loss in efficiency from having the entrant, which is relatively inefficient, produce industry output in excess of q^M. Explicitly, one can derive

$$\Delta\text{SW} = \frac{3(a-c)^2 - 4(a-c)s - 4s^2}{12(a-c)^2} - s\frac{2(a-c-2s)}{3(a-c)^2},$$

which can be rewritten more compactly as

$$\Delta\text{SW} = \frac{(a-c-2s)^2}{4(a-c)^2},$$

which is strictly positive. ΔSW is independent of λ because there is no accommodation.

If $s < \frac{1}{2}(a-c) - 2\lambda c$ (region A^s in Figure 3 in the paper), then the incumbent accommodates. The expression for ΔSW now consists of three terms. The first records the change in social welfare if production were distributed efficiently. The second term records the social loss from having the entrant, rather than the incumbent, produce q^E, under the assumption that the incumbent's marginal cost is c. In fact, however, the incumbent's marginal cost is only $(1-\lambda)c$ for output less than q^M. The third term, which we will refer to as the *excess capacity effect*, corrects for this. Explicitly, one can derive that

$$\begin{aligned}\Delta\text{SW} &= \frac{5(a-c)^2+8(a-c)(\lambda c-s)-4\lambda^2c^2+8s\lambda c-4s^2}{27(a-c)^2} \\ &\quad -\frac{4s(2(a-c)-2\lambda c-4s)}{9(a-c)^2}-\lambda c\frac{4(a-c-4\lambda c-2s)}{27(a-c)^2}.\end{aligned}$$

Collecting terms in λ, we can write this more compactly as,

$$\Delta\text{SW}=\frac{44\left(s-\frac{5}{22}(a-c)\right)\left(s-\frac{1}{2}(a-c)\right)}{27(a-c)^2}-\lambda c\frac{4(a-c-14s-11\lambda c)}{27(a-c)^2}.$$

From this, one can see that if $\lambda=0$ then $\Delta\text{SW}=0$ if $s=5(a-c)/22$ or $s=(a-c)/2$, which are the two endpoints of the loss region L^s in Figure 3 in the paper.

Finally, if $s>(a-s)/2$ (Region C^s in Figure 3), then the entrant does not enter and $\Delta\text{SW}=0$.

A.1.1 $s=0$, and $F>0$.

The general expressions for ΔSW when $s=0$ and $F>0$ are as follows.

If $F<(a-c)^2/(16b)$ and $\lambda>(a-c)/4c$ (Region B^F in Figure 5 in the paper), then the entrant enters but the incumbent does not accommodate. The equilibrium outcome in this case is precisely that of the subgame perfect equilibrium of the Stackelberg game. ΔSW thus equals the (normalized) difference in welfare between Stackelberg competition and monopoly. This ΔSW is the sum of two terms. The first is the gain in social welfare which would occur if production were allocated efficiently. Since $F>0$, efficient production means that all production is handled by the incumbent and the entrant does not, in fact, enter (does not incur the setup cost F). The second term subtracts off the loss in efficiency from duplication of F. Summarizing:

$$\Delta\text{SW}=\frac{1}{4}-\frac{8bF}{3(a-c)^2}. \tag{1}$$

If $F\leq(a-c-c\lambda)^2/(9b)$ and $\lambda\leq(a-c)/4c$ (Region A^F in Figure 5 in the paper), then the entrant enters and the incumbent accommodates. The expression for ΔSW now consists of three terms. The first two terms are analogs of those above. The third and last term is the excess capacity effect described in the previous subsection. Explicitly, one can derive:

$$\Delta\text{SW} = \frac{5(a-c)^2 + 8(a-c)\lambda c - 4\lambda^2 c^2}{27(a-c)^2} - \frac{8bF}{3(a-c)^2} - \lambda c \frac{4(a-c-4\lambda c)}{9(a-c)^2}.$$

Collecting terms in λ, we can write this more compactly as

$$\Delta\text{SW} = \frac{5}{27b} - \frac{8F}{3(a-c)^2} - \lambda c \frac{4(a-c-11\lambda c)}{27(a-c)^2}.$$

Note in particular that if $\lambda = 0$ then $\Delta\text{SW} = 0$ if $F = 5(a-c)^2/(72b)$, which is the lower endpoint of the loss region L^F in Figure 5 in the paper.

Finally, if either $F > (a-c-c\lambda)^2/(9b)$ and $\lambda \leq (a-c)/4c$ *or* $F > (a-c)^2/(16b)$ and $\lambda > (a-c)/4c$ (Region C^F in Figure 5 in the paper), then the entrant does not enter and $\Delta\text{SW} = 0$.

B Single entrant. *Dixit* Scenario.

Suppose that the incumbent initially has no capacity in place, but that it can install capacity just prior to the entry decision of its rival. As in the paper, we refer to this as the *Dixit* scenario. As in the *monopoly capacity* scenario, entry under the *Dixit* scenario can lower welfare only if parameters fall within the accommodation region, A^s or A^F. One can verify that accommodation region A^s is the same under either the *monopoly capacity* scenario or the *Dixit* scenario, and similarly for A^F. One can also verify that the only change to the welfare calculation within the A^s or A^F is that the excess capacity effect vanishes. As a consequence, changing from the *monopoly capacity* scenario to the *Dixit* scenario shrinks the loss region, the region in the $\lambda \times s$ or $\lambda \times F$ parameter space for which entry can cause social welfare to decrease.

Figure A1 shows the loss regions for the *monopoly capacity* scenario and *Dixit* scenario when $F > 0$. The loss regions for $s > 0$ are nearly identical and are therefore not exhibited.

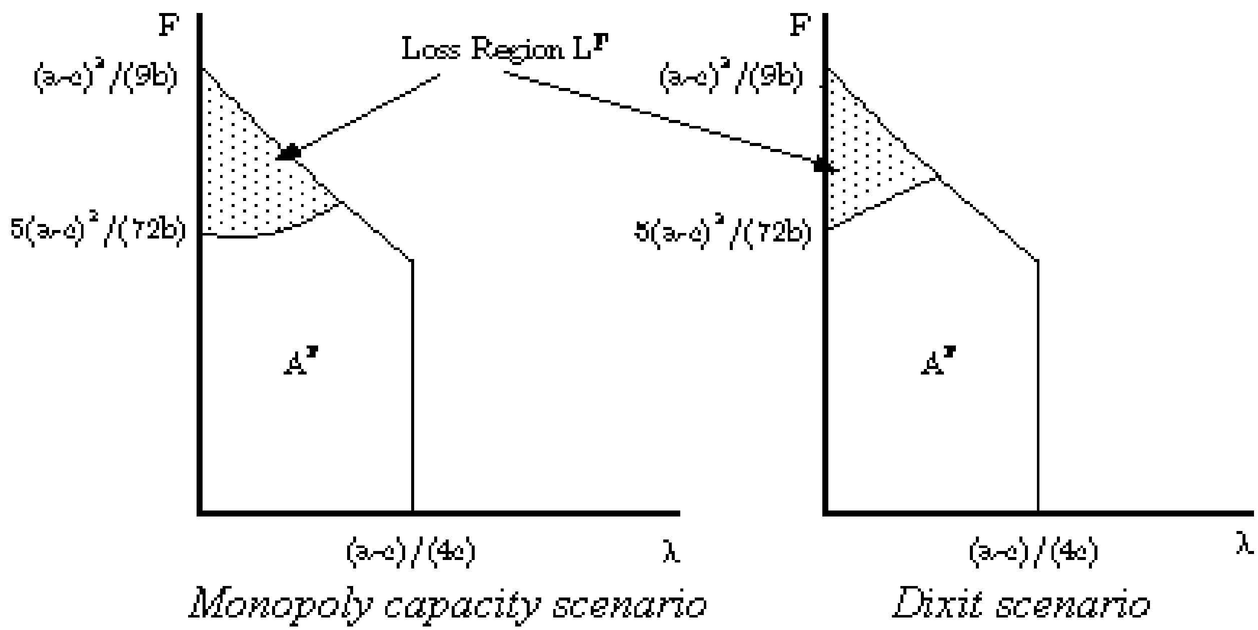

Figure A1. s=0, F>0, c/a=1/3, and one entrant

Outside of the accommodation region, the *Dixit* scenario causes more extensive modifications to the social welfare calculation. These modifications do not bear on the issue of whether entry is harmful and so we will not detail them here.

C Many Entrants.

We interpret the single entrant case as being one in which potential entrants are heterogeneous, with few "favored" entrants. Here, we briefly consider the opposite assumption: there is a large pool of homogeneous potential entrants. We will concentrate on the case $s = 0, F > 0$. We view this case as relatively interesting because the number of entrants is then endogenous. As our welfare thought experiment, we continue to compare welfare under free entry to welfare under monopoly. For simplicity, we will consider only the *monopoly capacity* scenario. Considering the *Dixit* scenario instead will alter the loss regions only in so far as the *Dixit* scenario eliminates the excess capacity affect.

Figure A2 is the analog of Figure 5 in the paper, except that now there are parameter regions in which more than one firm will enter. Starting at the top of the diagram, there is a region of F values for which only one firm can enter and earn positive profits. Continuing down the F axis, one encounters regions where $n = 2$, $n = 3$, $n = 4$, $\ldots$ firms can profitably enter the market. Within each of these regions, there is an accommodate and a non-accommodate subregion.

Figure A2 also shows the subregions (shaded) of the accommodation regions for which entry lowers welfare. As in the case of a single potential entrant, the vertical height of each loss region declines in λ. Moreover, the area of each loss region relative to its respective accommodation region declines in the number of firms. For $n = 4$, the loss region is so small as to be almost invisible. For $n \geq 5$, there is no loss region at all. These observations are independent of c/a. For $c/a = 1/3$, the critical λ (which occurs for F such that $n = 2$) is $\lambda^* \approx 0.37$.

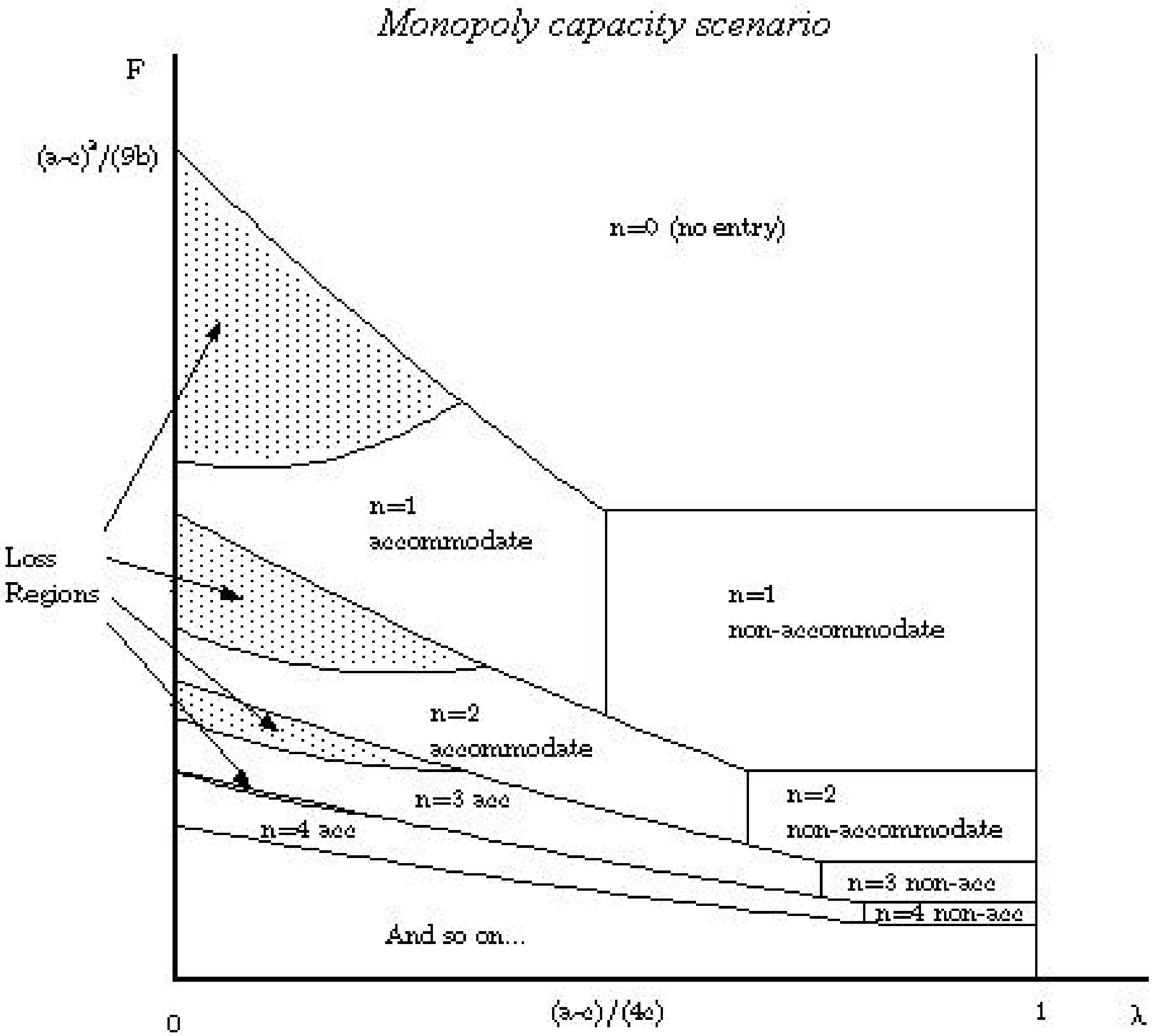

Figure A2. s=0, F>0, and many homogeneous potential entrants