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Beyond Simple Profit Maximization in Uncertain Markets: How Innovation and Entry Change Supply Curves and Producer Surplus

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Abstract
This article challenges the conventional wisdom that decreases in total revenue always cause firms to be worse off. Instead, innovations and entry causing clockwise rotations or parallel supply shifts can increase producer surplus even when total revenue decreases. Textbooks claiming producers are worse off when total revenue declines are misleading because producer surplus increases initially even when revenue declines. Schumpeterian entrepreneurs who create innovations that benefit low-productivity/high-marginal-cost production cause clockwise supply rotations, and entrepreneurs that create innovations that provide similar benefits to both high- and low-productivity producers cause parallel supply shifts. The article's focus on entry and innovation illustrates the importance of Julian Simon's argument that focusing on allocation rather than innovation often leads to wrong conclusions and Alchian's argument that uncertain foresight makes profit maximization meaningless as a guide to specifiable action. Though producer surplus increases then declines, consumer and total

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surplus always increase. Producer surplus eventually declines when clockwise supply rotations lead supply to be more elastic than demand, where the price-reducing effect of the innovation dominates the cost-reducing and quantity-enhancing effects. Entry and innovation that generate rightward parallel supply shifts cause producer surplus to increase at an increasing rate when supply is elastic until the inflection point where supply is unit elastic. Beyond the inflection point, parallel rightward supply shifts cause producer surplus to increase at a decreasing rate and, eventually, decline. Last, we conduct a numerical 3D analysis illustrating how entry and innovation that cause supply to rotate and shift affect producer surplus.

JEL Codes: A1, D2, D6, O3
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I. Introduction

Schumpeter ([1911] 1934, 1942) views entrepreneurs as generating and using new knowledge to serve customers better. He defines *invention* as generating new ideas and *innovation* as applying the ideas. Innovation is how entrepreneurs drive economic development. Schumpeter ([1911] 1934, p. 66) discusses five types of innovation: (1) offering new goods or a new quality of a good, (2) finding new ways to produce a good, (3) offering an existing good to a market where the good is not available, (4) finding new supplies of inputs, and (5) organizational innovations such as creating joint stock companies, monopolizing an industry, or making an industry more competitive. Each source of innovation is important and introduces various uncertainties into entrepreneurs' decision-making. In this paper we focus on finding new ways to produce a good and how the entrepreneurs' decision-making calculus varies based on market conditions and how different types of innovations and entry affect total surplus. The prevalence of different types of innovations and entry calls for a more systematic analysis of their efficiency and distributional implications. We thus study how different types of innovations and entry affect total surplus and its distribution between consumers and producers. We take a systematic approach and study innovation and entry that cause three types of changes in the supply curve: clockwise rotations (making the supply curve flatter), parallel shifts, and both. Entry and innovation illustrate the importance of focusing not only on allocation but also on reducing scarcity through innovation.

Consider Robbins (1935), who defines economics as the study of allocating scarce resources among competing uses. Simon (1989), in contrast, writes that allocation is the most important short-term economic activity when technologies are fixed but that with changing technologies, allocation-centered thinking is often misleading. Simon argues that because of new technologies that reduce the prices of commodities, Hotelling's (1931) classic resource-economics article comes to the wrong conclusions in all known situations. Simon also notes that in a single-person economy, even Robinson Crusoe is more concerned about developing technological improvements to alleviate scarcity than optimally allocating his time.

Understanding how entry and innovations affect markets is becoming increasingly important, given the rapid pace of technological progress that dramatically affects many industries and forces firms to adapt to changing environments. Alchian (1950, p. 211) argues that uncertain foresight makes profit maximization meaningless as a guide to specifiable action. He argues that positive profits, not maximum profits, measure success under uncertainty and that successful firms survive and nonprofitable firms disappear. Alchian writes that firms survive (1) because they are relatively superior to other firms in adapting to market changes and (2) because of luck, which becomes more important the greater the uncertainty. But Alchian adds that the environment may adapt to the successful firms more than the reverse.

Scholars have long recognized that the efficiency and distributional effects of innovation and entry crucially depend on the nature of the supply shift caused by these forces. They have also long recognized the difficulties of predicting supply shifts associated with technological progress and entry (for example, Lindner and Jarrett, 1978; Alston et al., 2004).[1] Yet much of the literature about the benefits of innovation and entry does not fully characterize the link between the nature of innovation and market outcomes. Lindner and Jarrett (1978, 1980), Rose (1980), Wise and Fell (1980), Martin and Alston (1997), and Wohlgenant (1996) suggest that a wide variety of innovations may cause clockwise rotations of the supply curve. Specifically, clockwise supply rotations are caused by innovations that benefit low-productivity/high-

[1] For example, Alston et al. (2004) write, "There has been much discussion in the published literature but as yet no consensus has been reached about how to determine the nature of the research-induced shift of the supply curve, whether it is parallel, pivotal, divergent or convergent . . . Accepting the lack of consensus on this issue, we consider the extreme cases of parallel and pivotal shifts."

marginal-cost production. Relatively recent agricultural innovations that have significantly boosted the food supply display these characteristics. These include genetic modifications to introduce herbicide tolerance, heat tolerance, and drought tolerance. Other examples include efficient irrigation technologies and disembodied technical changes such as optimal irrigation timing, deficit irrigation, and no-till practices.[2] Innovations that benefit low-productivity/high-marginal-cost production have also been prevalent in the energy industry. A prominent example is fracking, which has allowed the exploitation of unconventional natural gas reserves. Other examples include innovations in biofuels and solar panels. Technological innovations have also significantly reduced the cost of offshore drilling for both oil and natural gas. These innovations have caused considerable entry into this high-cost segment of production.

Public policies can also create clockwise rotations in supply. These include policies designed to assist marginal producers, such as smallholders or owners of marginal land. Insurance subsidies that reduce the expected marginal cost of production likely cause clockwise supply rotations since insurance provides higher benefits to low-productivity/high-cost agricultural producers. Previous studies (Alston et al. 2004; Phillips et al. 2001) also argue that innovations adopted in the same proportion by producers with different marginal costs cause clockwise supply rotations. The entry of identical firms also causes clockwise supply rotations.

Parallel shifts are caused by the entry of firms that are evenly distributed along the marginal-cost spectrum and by innovations that create similar benefits to both the high-productivity/low-cost producers and the low-productivity/high-cost producers. Embodied innovations that likely produce parallel shifts in agricultural supply include high-yielding crop varieties, fertilizers, pesticides, and insecticides. These advances were mainly introduced and widely adopted during the green revolution in the 1960s. Variable-rate technologies (which measure soil nutrients and apply specific nutrient rates) have also been adopted across land types. Examples of parallel-shifting disembodied technological progress include changes in crop rotation, planting date, density, and tillage practices. Additionally,

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[2] Innovations can be embodied or disembodied. Embodied innovations are specific products or processes adopted by farmers that reduce marginal production costs. Disembodied innovations consist of knowledge and management practices that translate into a reduction in marginal production cost but are not embodied in a specific product or process.

public policies, such as production subsidies that benefit the entire spectrum of producers, can cause a parallel shift in supply.

In his prominent textbook, Mankiw (2019) uses farming as an example in which production innovations cause a parallel supply shift to the right. The parallel supply shift causes total revenue to decrease since demand is inelastic. Mankiw states that farmers are worse off when total revenue declines. We show below, however, that Mankiw is incorrect since producer surplus increases at first when total revenue decreases, though eventually producer surplus will fall as well. We find that the efficiency and distributional implications of innovation and entry crucially depend on the specific nature of the supply change and the supply curve's position at the onset of the innovation or entry. Our analysis shows that entry and innovations causing clockwise rotations and parallel shifts in supply can increase producer surplus even when firms earn less total revenue. We show that a lower elasticity of supply relative to demand increases producer surplus and benefits producers. However, how relative elasticities affect producer surplus depends on the type of entry and innovation. For example, entry and innovations causing rightward parallel shifts in supply cause producer surplus to increase at an increasing rate in the elastic portion of the demand curve. The inflection point is where the elasticity of supply is unit elastic. In the inelastic range, producer surplus increases at a decreasing rate until it reaches a maximum and decreases to zero when the price is zero. Total surplus always increases because the increases in consumer surplus are large enough to more than compensate for the fall in producer surplus. We also demonstrate how producer surplus is affected when there are concurrent rotations and parallel shifts of supply.

Section 2 develops the linear model. Section 3 demonstrates how entry and innovation that cause clockwise supply rotations affect producer surplus. Section 4 shows how entry and innovation that cause rightward parallel supply shifts affect producer surplus. Section 5 discusses how simultaneous supply rotations and shifts affect producer surplus. The conclusion discusses who gains and loses from different types of entry and innovation.

II. Consumer and Producer Surplus with Linear Demand and Supply Curves

Readers who want to skip the math sections are invited to evaluate the figures to see the main results about how different types of changes in supply curves affect producer surplus in different ways. For the rest, assume that the demand curve is

$$P_D = a - bQ \qquad (1)$$

and the supply curve is

$$P_S = c + eQ, \qquad (2)$$

where P_D is the demand price, P_S is the supply price, a is the intercept of the demand curve, c is the intercept of the supply curve, b is the slope of the demand curve, e is the slope of the supply curve, and $a>c$.

Setting $P_D = P_S$, the equilibrium quantity Q^e is

$$Q^e = \frac{a-c}{e+b}. \quad (3)$$

Substituting Q^e into P_S or P_D, the equilibrium price, P^e, is

$$P^e = \frac{cb+ae}{e+b}. \qquad (4)$$

We assume $P_s \geq 0$, $P_D \geq 0$, $e \geq 0$, and $b>0$.

The elasticity of supply (E_s) is

$$E_S = \frac{1}{slope}\frac{P^e}{Q^e}. \qquad (5)$$

Substituting equation (3) for Q, equation (4) for P, e for the slope, and simplifying, E_s is

$$E_S = \frac{1}{e}\frac{cb+ae}{a-c}. \qquad (6)$$

When $c=0$, $E_s=1$; when $c>0$, $E_s>1$; and when $c<0$, $E_s<1$. In other words, the supply is elastic when $c>0$ and inelastic when $c<0$, regardless of the slope.

Consumer surplus (CS) is simply the area between demand and the equilibrium price between zero quantity and equilibrium quantity:

$$CS = \frac{1}{2}(a - P^e)Q^e = \frac{1}{2}\left(a - \frac{cb+ae}{e+b}\right)\frac{a-c}{e+b} =$$
$$\frac{1}{2}\left(\frac{ae+ab-cb-ae}{e+b}\right)\frac{a-c}{e+b} = \frac{1}{2}b\left(\frac{a-c}{e+b}\right)^2 \qquad (7)$$

When $c > 0$, producer surplus (PS) is simply the area between the equilibrium price and supply from zero quantity to the equilibrium quantity:

$$PS = \frac{1}{2}(P^e - c)Q^e = \frac{1}{2}\left[\frac{cb+ae}{e+b} - c\right]\frac{a-c}{e+b} = \frac{1}{2}e\left(\frac{a-c}{e+b}\right)^2$$
$$(8)$$

Total surplus (TS) with an elastic supply is

$$TS = \frac{1}{2}\left(\frac{a-c}{e+b}\right)^2 (e+b). \qquad (9)$$

When $c < 0$, the calculation of producer surplus is slightly more complicated because the area above supply is no longer a triangle. More specifically, *PS* is the difference between the price and the supply curve after subtracting the area of the triangle that is below zero. PS_I in equation (8) represents *PS* when supply is inelastic:

$$PS_I = \frac{1}{2}\left[-\frac{c^2}{e} + e\left(\frac{a-c}{e+b}\right)^2\right] \qquad (10)$$

And *TS* with an inelastic supply (c<0) is

$$TS_I = \frac{1}{2}\left(\frac{a-c}{e+b}\right)^2 (e+b) - \frac{c^2}{2e}. \qquad (11)$$

Armed with this model, we now examine how entry and innovations that cause clockwise rotations, rightward parallel shifts, and intercept and slope changes in supply affect the equilibrium and surplus.

III. Entry and Innovation That Cause Clockwise Rotations of Supply

As discussed above, innovations that benefit low-productivity/high-marginal-cost production and entry of identical firms cause clockwise supply rotations.

*A. Entry and Innovation That Cause Clockwise Rotations of Elastic Supply (*c>0*)*

When the largest cost reductions are for the highest-marginal-cost producers, entry of identical firms and innovations cause clockwise supply rotations. When there are clockwise supply rotations, e decreases while c remains constant. The effect of technical change or entry on CS can be seen by taking the derivative with respect to e:

$$\frac{\partial CS}{\partial e} = \frac{1}{2}b(a-c)^2(-2)\frac{1}{(e+b)^3} = -\frac{b(a-c)^2}{(e+b)^3} =$$
$$-\frac{b}{e+b}Q^2 < 0 \qquad (12)$$

In other words, innovation and entry reduce prices and increase consumer surplus.

The effect of technical change or entry on *PS* can be seen by taking the derivative with respect to *e*:

$$\frac{\partial PS}{\partial e} = \frac{1}{2}\left(\frac{a-c}{e+b}\right)^2 + \frac{1}{2}e(a-c)^2(-2)\frac{1}{(e+b)^3} = \left(\frac{1}{2} - \frac{e}{e+b}\right)Q^2 \qquad (13)$$

When *e*>*b* and $\partial PS/\partial e < 0$, innovations and entry decrease *e* and increase *PS*. In contrast, when *e*<*b* and $\partial PS/\partial e > 0$, innovations and entry decrease both *e* and *PS*. Thus, innovation and entry that cause clockwise rotations in the supply curve increase producer surplus only when supply is sufficiently inelastic *relative to demand.* The mechanism underlying these results is clear. As supply rotates clockwise, it unleashes two opposing forces: it decreases price and raises quantity. The former decreases producer surplus, and the latter raises it. The overall result depends on the relative strength of these forces. When demand is elastic (inelastic) *relative to supply*, the quantity (price) effect dominates, and producer surplus rises (decreases).

Note that the condition above does not depend upon c or a even though those parameters also affect supply and demand elasticities. This is because these parameters do not affect the *relative* elasticity of supply and demand. To see this, consider the following measure of relative elasticities:

Elasticity of demand at equilibrium: $\varepsilon_d = -\frac{1}{b}\frac{P^e}{Q^e}$ (14)

Elasticity of supply at equilibrium: $\varepsilon_s = \frac{1}{e}\frac{P^e}{Q^e}$ (15)

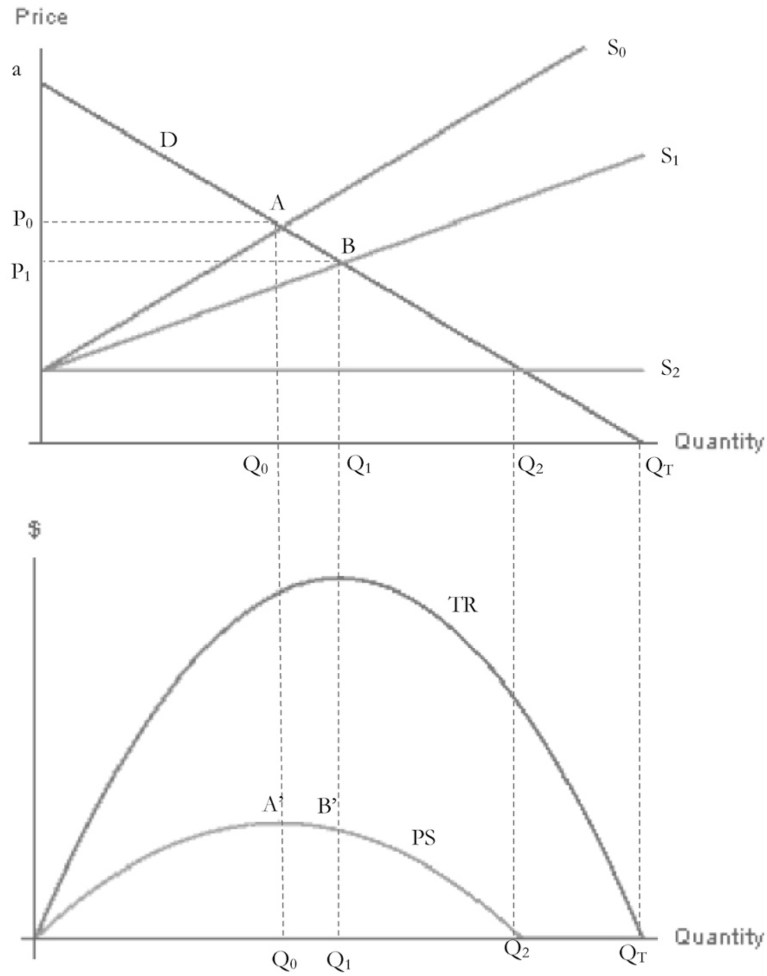
Using these measures, we can define relative supply elasticity as $\frac{|\varepsilon_s|}{|\varepsilon_d|} = \frac{b}{e}$. While intercepts c and a affect P^e and Q^e, equilibrium price and quantity cancel out and do not affect the relative elasticity. This is because equilibrium prices and quantities affect supply and demand elasticities proportionally, thereby leaving the ratio unaffected.

We categorize supply as relatively inelastic if $\frac{\varepsilon_s}{\varepsilon_d} < 1$, which is equivalent to $e > b$.

The supply curve rotates clockwise in agriculture when technological improvements mainly increase low-quality land yields (Passioura et al., 2010). Likewise, entry of identical firms rotates the supply curve. Since the supply curve becomes more horizontal, the cost advantage of high-quality land is reduced.

Figure 1 illustrates how a technological innovation that causes a clockwise supply rotation affects *PS* when the supply curve is elastic.[3] The supply curve is rotated clockwise by varying the slope while keeping the intercept (c) constant. Miller et al. (1988) show that as supply rotates clockwise with c constant, *PS* reaches a maximum when $e=b$. S_0 in the upper portion of figure 1 illustrates a supply curve that corresponds to the maximum *PS*, where its slope (e) is the same as the slope of the demand curve (b).

Figure 1. Producer surplus when there are clockwise rotations of elastic supply curves



[3] In figure 1, demand is $P_D=10-0.5Q$ and the supply curves are $P_S= 2+eQ$. S_0 is when $P_S=2+0.5Q$ and S_1 where $P_S=2+0.3Q$.

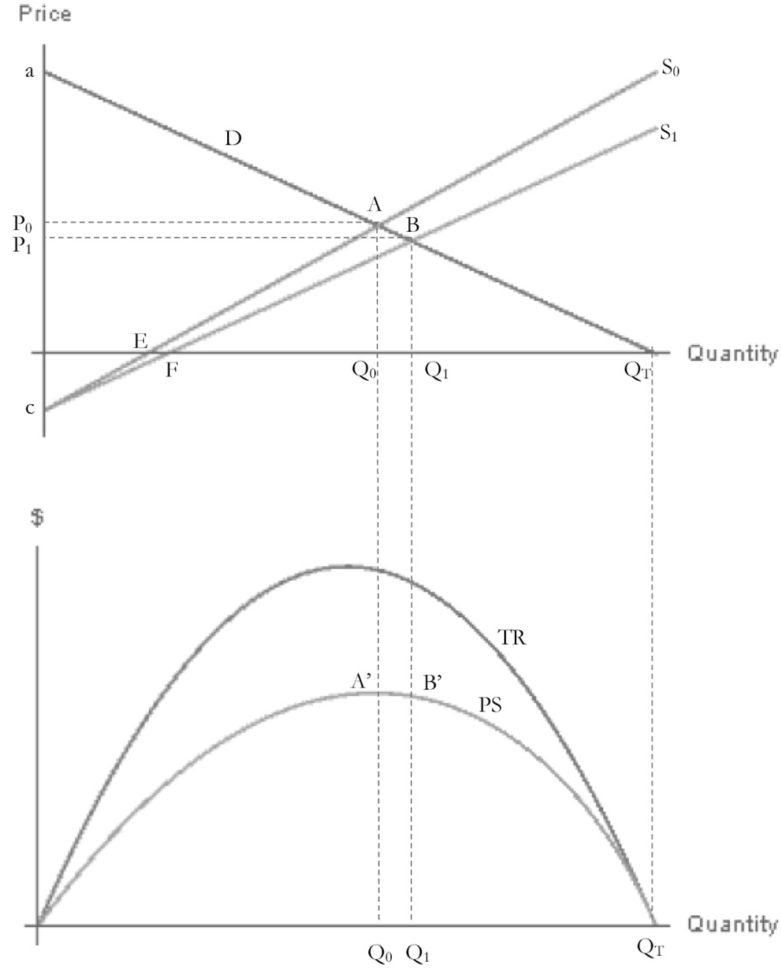
In figure 1, the maximum *PS* occurs at Q_0, where $e=b$. Since $e>b$ at quantities less than Q_0, innovations increase *PS*. When $e<b$ at quantities greater than Q_0, innovations decrease *PS* until *PS*=0 when the supply curve is perfectly elastic (supply curve S_2). Figure 1 shows that when supply is elastic, innovations benefit society as a whole but producers benefit only to the extent that the supply elasticity remains low relative to the demand elasticity.

B. Entry and Innovation That Cause Clockwise Rotations of Inelastic Supply Curves ($c<0$)

Figure 2 illustrates how a clockwise rotation of an inelastic supply curve from S_0 to S_1 affects *PS*, where S_1 is the post-innovation supply curve.[4] *PS* with an inelastic supply curve is the difference between the price and the supply curve after subtracting the area of the triangle that is below zero. *PS* for supply curve S_1 is area P_1BF0 (area P_1Bc minus area $0Fc$). Notice that the *PS* area in the upper diagram does not include anything below the x-axis.

[4] *D* is $P_D= 10-0.5Q$ and *S* is $P_S=-2+eQ$. S_0 is $P_S=-2+Q$. S_1 is $P_S=-2+0.7Q$.

Figure 2. Producer surplus when there is a clockwise rotation of inelastic supply curves



To determine what effect changes in e have on producer surplus when supply is inelastic, differentiate equation (10) with respect to e:

$$\frac{\partial PS}{\partial e} = \frac{1}{2}\left[\frac{c^2}{e^2} + Q^2\left(1 - 2e\left(\frac{1}{e+b}\right)\right)\right] \quad (16)$$

While the first term on the right-hand side of equation (16) is positive (decreases in e reduce PS), the second term can be positive or negative depending on the size of b relative to e. If $b \geq e$, then $\partial PS/\partial e > 0$. A positive sign for $\partial PS/\partial e$ means that PS will decrease with innovation and entry. When $b=e$, the second term in equation (16) becomes $1-(2e/2e)=0$, and $\partial PS/\partial e > 0$. Finally, if $b<e$, the second term is negative, and the sign of $\partial PS/\partial e$ can be positive *or* negative

(Karagiannis and Furtan 2002). This means that unlike with an elastic supply curve, when the supply curve is inelastic, *PS* is at its maximum when $b<e$. The lower portion of figure 2 shows that *PS* increases between 0 and Q_0 where $b<e$. *PS* decreases between Q_0 and Q_T where $b<e$, $b=e$, and $b>e$.

*C. Entry and Innovation That Cause Clockwise Rotations of Elastic, Unit, and Inelastic Supply Curves (*c>0, c=0, c<0*)*

Figure 3 shows how different intercepts (c) change how clockwise supply rotations (reductions in e with c constant) affect *PS*. Each *PS* curve in figure 3 is generated by changing e while keeping the level of c constant. The origin in figure 3 is where $c=a=10$. Since the supply and demand intercepts are equal, firms do not produce ($Q=0$) and $PS=0$. *PS* is higher when the supply intercept (c) is below the demand intercept (a). When supply is elastic ($c>0$), decreases in c increase the length and height of the *PS* curves. When supply is inelastic ($c<0$), reductions in c continue to increase the height of the *PS* curves but not the length. As discussed above, when the supply curve is elastic, *PS* is at its maximum level when $e=b$ (Miller et al. 1988).[5] When the supply curve is inelastic, *PS* reaches its maximum when $b<e$.

[5] With a linear demand curve, the supply curves that correspond to the maximum producer point on *PS* are parallel when the supply curve is elastic. In our simulation, when D is $P_D=10-0.5Q$, five elastic supply curves and one unit-elastic supply curve that correspond to the maximum point on the PS graph in figure 4 are S1=5+0.5Q, S2=4+0.5Q, S3=3+0.5Q, S4=2+0.5Q, S5=1+0.5Q, and S6=0.5Q. When the supply curve is inelastic, *PS* is at its maximum when $b<e$, and the supply curves that correspond to the maximum *PS* are not parallel but become more inelastic (e increasing) as c decreases. When supply is inelastic, five of the supply curves that correspond to the maximum PS are S7=−1+0.532Q, S8=−2+0.6025Q, S9=−3+0.6886Q, S10=−4+0.7813, and S11=−5+0.877183.

Figure 3. 3D graph showing how clockwise rotations of supply affect producer surplus when *c* varies

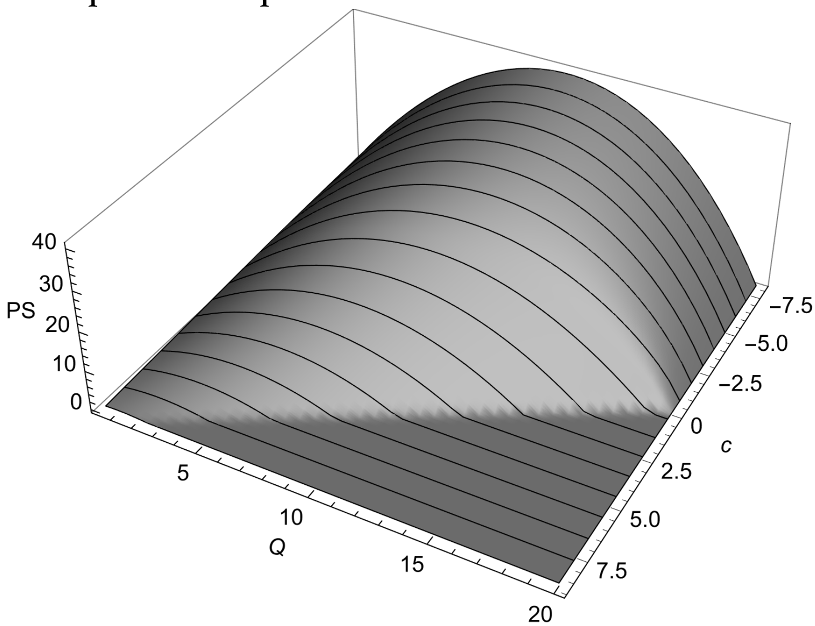


Figure 4 depicts various *PS* and *TS* curves that are generated by changing *c*. Movements along all curves are caused by reducing *e* while holding *c* constant (clockwise rotations in the supply curve). There is only one *CS* curve because changes in *c* do not change its position, and *CS* always increases at an increasing rate.

Figure 4: How clockwise rotations of supply affect Consumer Surplus (*CS*), Producer Surplus (*PS*), and Total Surplus (*TS*)

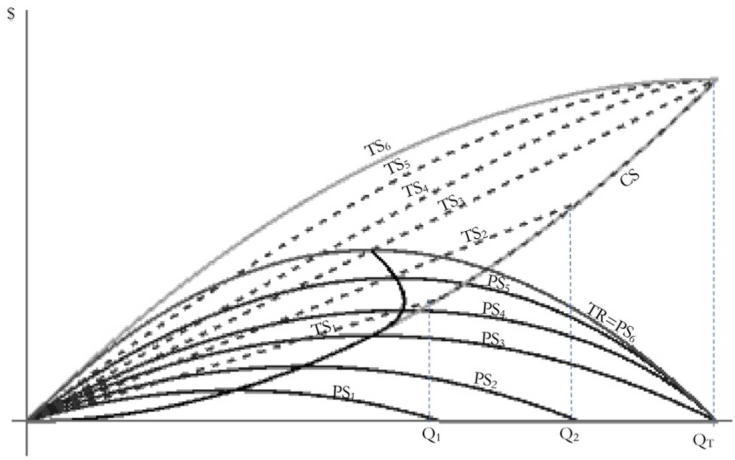


Figure 4 shows that when there are clockwise rotations in supply, the maximum point of each *PS* curve lies along a backward-bending curve that starts at the origin and ends at the highest point of the *TR* curve. Producer surplus increases not only when supply is elastic and unit elastic but also at first when supply is inelastic. Eventually, the maximum point curve has a backward bend, ending at the maximum point of the total revenue curve.

Since there is only one *CS* curve, $TS_i=CS+PS_i$, PS_1, and PS_2 correspond to elastic supply curves ($c>0$). When $c>0$, *TS* increases at a constant rate until the supply curve is perfectly elastic ($e=0$) where $PS=0$ and $TS_i=CS$. $TS_1=CS$ at quantity Q_1 and $TS_2=CS$ at Q_2.

When supply is inelastic ($c<0$), *TS* increases at a decreasing rate up to where $TS_i=CS$ at Q_T. At Q_T, the good is not scarce, so people can get all they want for free. For all inelastic supply curves, *TS* and *CS* are maximized at Q_T. When all curves are included, and when supply is inelastic ($c<0$), total surplus increases at a decreasing rate until total surplus is equal to consumer surplus.

In figure 4, the more inelastic the supply curve, the greater the *TS* until $PS_6=TR$, when the supply curve is perfectly inelastic. The more elastic the supply curve, the more linear the *TS* curve. The more inelastic the supply curve, the larger the total surplus. In other words, *TS* is larger the smaller c is.

While likely very relevant in food markets today, policy and public discussions generally overlook these issues. Innovations constantly reduce marginal production costs in what have historically been considered marginal production areas. The overall effect of these innovations on consumers and producers critically depends on supply elasticity. Yet a disconnection between these measures is generally observed. If taxpayers subsidize research and development in agriculture (as is typically the case) and supply is inelastic, our analysis shows that producers, instead of consumers, will accrue a large share of the benefits from innovation. Therefore, our analysis suggests that, under these conditions, the policy will likely result in cross-subsidization instead of large societal gain.

IV. Entry and Innovation That Cause Parallel Shifts of Supply

As discussed above, rightward parallel supply shifts are caused by the entry of evenly distributed firms along the marginal-cost spectrum and innovations that create similar benefits to both the high-productivity/low-cost producers and the low-productivity/high-cost producers.

*A. Entry and Innovation That Cause Parallel Shifts of Elastic Supply (*c*>0)*

How does innovation or entry that causes parallel rightward shifts of the supply curve affect market surplus? Innovation and entry that cause parallel shifts to the right reduce *c*. Equation (17) shows how innovation and entry that lower *c* affect *CS*:

$$\frac{\partial CS}{\partial c} = -b\,\frac{a-c}{(e+b)^2} = \frac{-b}{e+b}\,Q \qquad (17)$$

Equation (17) is always negative and shows that consumer surplus increases when innovation and entry cause parallel shifts.

To determine how *PS* changes after a change in *c* when supply is elastic (*c*>*0*), differentiate (8) with respect to *c*:

$$\frac{\partial PS}{\partial c} = -e\,\frac{a-c}{(e+b)^2} = -\frac{e}{e+b}\,Q \qquad (18)$$

The expression is always negative. Thus, innovation and entry that cause parallel supply shifts increase *PS* when c≥0. Since innovation and entry increase both *CS* and *PS* when *c*≥*0*, *TS* also increases.

*B. Entry and Innovation That Cause Parallel Shifts of Inelastic Supply Curves (*c<0*)*

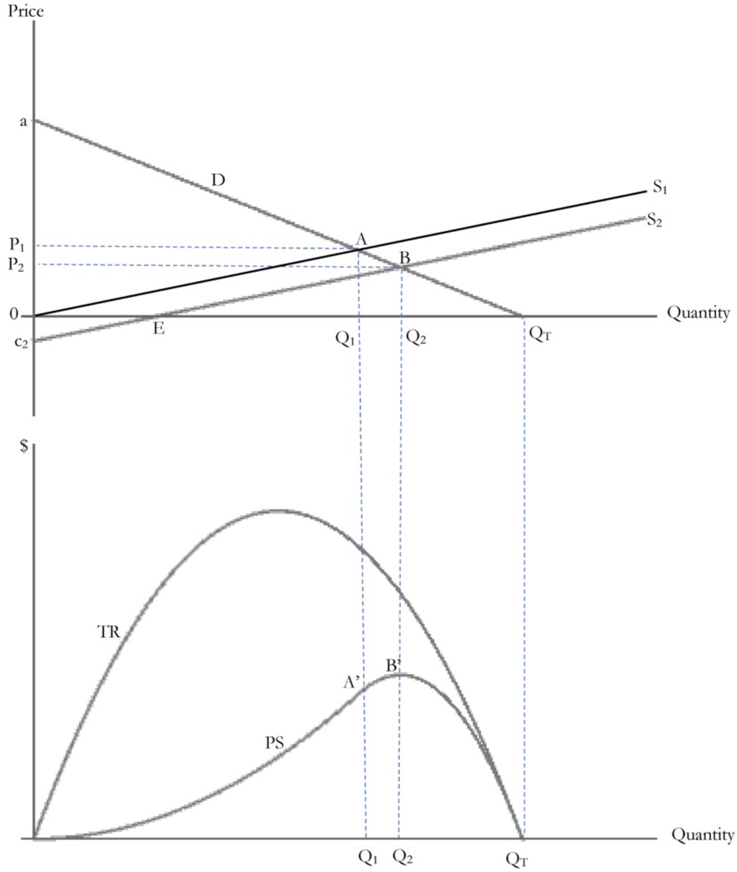
To calculate how innovations that cause parallel shifts affect *PS* when supply is inelastic (*c*<*0*), differentiate equation (10) with respect to *c*:

$$\frac{\partial PS}{\partial c} = -\frac{c}{e} - eQ\left(\frac{1}{e+b}\right) \qquad (19)$$

Since *e*>*0* and *b*>*0*, the second term in equation (19) is negative, and since *c*<*0*, the first term is positive. This means that the sign on equation (19) is indeterminate. Karagiannis and Furtan (2002) show that when the sum of the absolute values of the supply and demand elasticities at the pre-innovation equilibrium is greater than one, parallel increases of linear inelastic supply curves will cause *PS* to increase. When the sum of the absolute values is less than one, parallel increases of linear inelastic supply curves will cause *PS* to decrease. When the sum of the absolute values of the elasticities equals one, *PS* remains unchanged.

Parallel shifts cause *c* to decrease while *e* remains constant. Figure 5 illustrates how parallel shifts of supply affect *PS*. Since S_1 is an inelastic supply curve (*c*<*0*), *PS* is area P_1BE0 (area P_1BC_1 minus area $0EC_1$). The lower portion of figure 5 illustrates how a continuum of parallel shifts in supply affect equilibrium quantity, *PS*, and *TR*.

Figure 5: How parallel supply shifts affect Producer Surplus

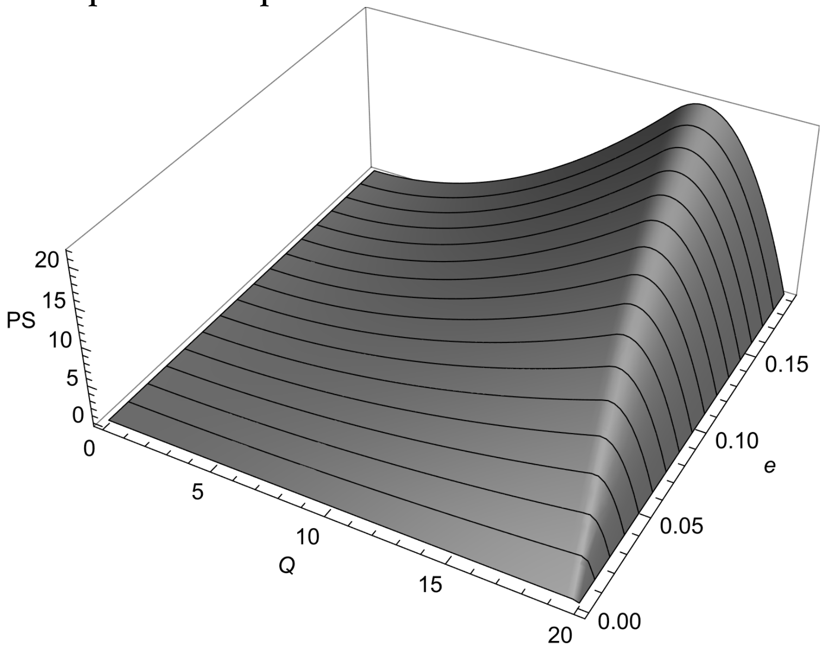


PS increases at an increasing rate in the elastic portion of the demand curve ($c>0$). The inflection point is where $c=0$ and the elasticity of supply is unit elastic. In the inelastic range ($c<0$), *PS* increases at a decreasing rate, reaches a maximum at point B', and then decreases to zero when the price is zero at Q_T. In other words, when supply is inelastic, parallel supply shifts push larger shares of the producer-surplus triangle into the negative quadrant until *PS* is zero at Q_T.

*C. Entry and Innovation That Cause Parallel Shifts of Elastic, Unit, and Inelastic Supply Curves (*c>0, c=0, *and* c<0*)*

Figure 6 illustrates how different levels of the slope parameter (*e*) affect how parallel shifts in supply (reductions in *c* with *e* constant) affect *PS*. In figure 6, each *PS* curve is generated by reducing *c* with *e* constant. In this case, entry and innovation reduce the supply intercept (*c*), which causes a movement along a given *PS* curve. Changes in the supply slope (*e*) change the position of the *PS* curve. When *PS≠0*, the more inelastic the supply, the higher the *PS*. For example, when the supply slope (*e*) is zero, the supply elasticity is perfectly elastic, so *PS=0* along the x-axis. The producer-surplus curve shifts upward as the supply slope (*e*) increases and becomes more inelastic. Except when supply is perfectly elastic or perfectly inelastic, *PS* increases when *TR* decreases.

Figure 6. 3D diagram showing how parallel shifts of supply affect producer surplus when *e* varies



Horowitz et al. (2013) show that when there are parallel shifts of linear supply curves, the maximum point on each *PS* curve in figure 6 lies along a line that begins at the top of the *TR* curve and ends at the bottom right corner of the *TR* curve. In other words, the maximum point of each *PS* curve in figure 6 lies along line $TB'Q_T$ in figure 5. Except when supply is perfectly elastic or perfectly inelastic, *PS* increases when *TR* decreases.

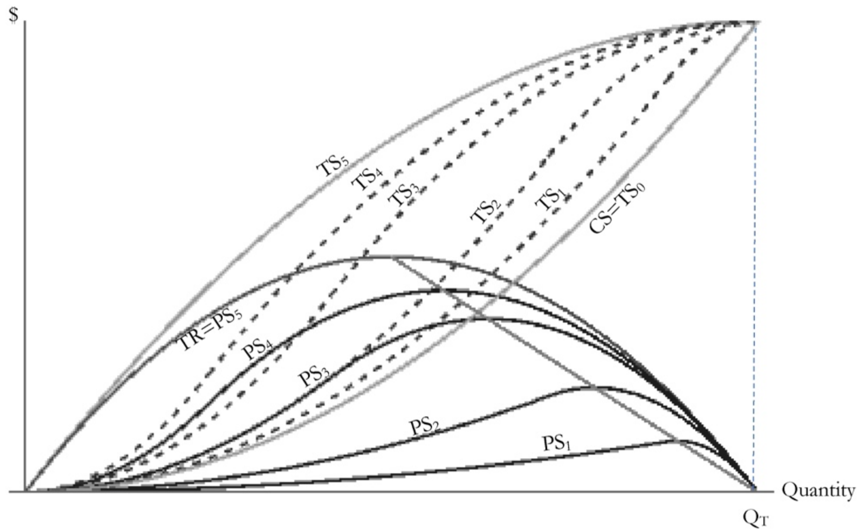
Mankiw (2019) is correct that parallel supply shifts cause *TR* to decrease when demand is inelastic. But he is inaccurate in stating that producers are worse off since *PS* increases when *TR* decreases, though *PS* eventually falls.

CS always increases at an increasing rate when there are parallel supply shifts (Horowitz et al. 2013). *TS* starts at zero, increases at an increasing rate up to where the supply is unit elastic, and then increases at a decreasing rate until the maximum *TS* occurs at Q_T (Horowitz et al. 2013).

V. How Changing Both the Supply Intercept *c* and Supply Slope *e* Affect *PS*

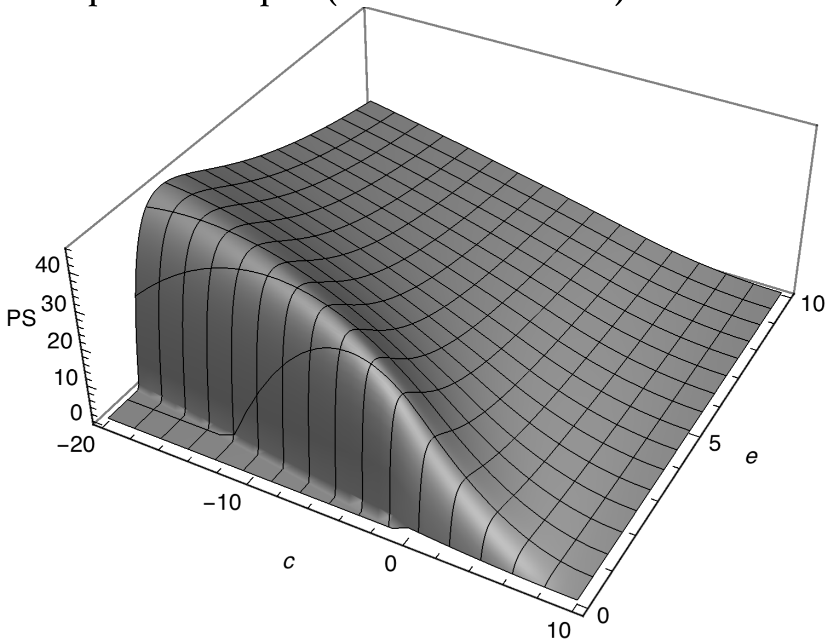
Figure 7 shows how the supply curve will shift when there is both a parallel supply shift and a clockwise supply rotation.

Figure 7: How parallel shifts of supply affect Consumer Surplus (*CS*), Producer Surplus (*PS*), and Total Surplus (*TS*)



Since there is no analytical solution for kinked supply changes when both *c* and *e* change, figure 8 numerically shows how changing both the supply intercept *c* and slope *e* affect *PS*. In deriving figure 8, we assume $P_D=a-bQ$, $a=10$, $b=0.5$, $P_S=c-eQ$, and the demand curve intersects the *Q*-axis at $Q=20$.

Figure 8. How changes in the supply intercept *c* and slope *e* affect producer surplus (*10≥e>0* and *10≥c≥-20*)



As shown on the *e*-axis (*e=0*) in figure 8, the supply curve is perfectly elastic, so there is no *PS*. When *c=10*, the supply and demand curve intercepts are equal (*a=c=10*) and *PS=0*, so any changes in slope *e* will not affect *PS*. As *e* decreases to 0, for a given *c*, *PS* increases, reaches a maximum, and then decreases to zero. Also, as *c* decreases, *PS* increases at first, then decreases, and *PS=0* when inelastic supply curves (*c<0*) intersect the *Q*-axis at *Q≥20*. At first, the maximum *PS* increases at an increasing rate as *c* decreases and *e* increases, as shown in figure 8, and then increases at a decreasing rate.

VI. Conclusion

Entry and innovations dramatically affect many industries. A wide range of stakeholders (for example, industry, policy makers, and consumers) are interested in how entry and innovation affect market conditions and the profitability of firms.

Entry and innovations causing clockwise rotations and parallel shifts in supply will at first increase producer surplus, but then beyond a certain point (*e=b*) they will reduce producer surplus. Total surplus always increases because the increases in consumer surplus are large enough to more than compensate for the fall in producer surplus.

Entry and innovations have both efficiency implications (that is, increasing total surplus) and distributional implications. Entry and innovations that cause both clockwise rotations of supply and parallel supply shifts will eventually increase the share of total surplus received by consumers.

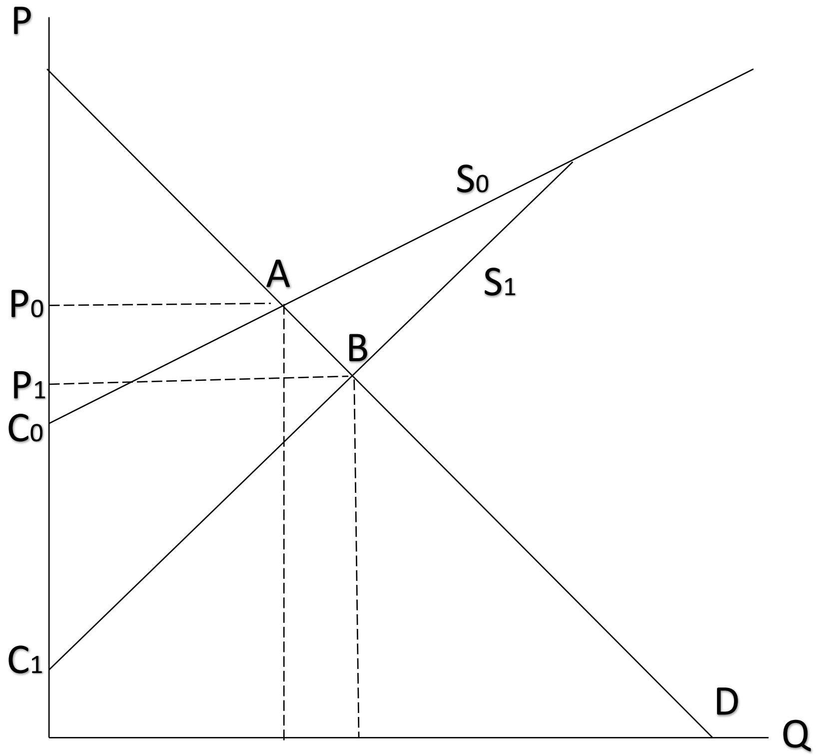
In a competitive market, all entry and innovations benefit consumers. However, not all entry and innovations benefit producers. Entry and innovations that cause clockwise supply rotations benefit producers only if they do not cause supply elasticity to increase too much relative to demand elasticity. Moreover, entry and innovations causing parallel shifts in supply benefit producers only if a small portion of the market output can be offered at no cost. The latter condition is much more plausible in reality, which means parallel supply shifts are more likely to benefit producers than clockwise rotations.

This exercise points to the importance of elasticities as critical in shaping the welfare implications of technological advances and entry decisions. Yet it also points to its limitations. A lower elasticity of supply relative to demand tends to increase the share of society's gains accrued by producers. Less generally understood, however, is that the validity of such an argument is not robust to the type of innovation being considered. Our analysis shows that entry and innovations causing rightward parallel shifts in supply can lower producer surplus while reducing supply elasticity.

Finally, the fact that some entry and innovations benefit consumers but not producers might suggest their overall effect on societal welfare is ambiguous. This analysis clearly shows that entry and technological innovations in competitive markets *always* benefit society as a whole. In other words, entry and innovations increase the sum of producer and consumer surplus in a competitive market regardless of the type of producers that adopt them, namely marginal (that is, high cost) or inframarginal (that is, low cost) producers.

We did not cover the fourth type of supply shift, which causes counterclockwise rotations of the supply curve with a lower y-intercept (figure 9). These innovations are those generally adopted by high-productivity/low-cost producers but not by low-productivity/high-cost producers. Counterclockwise rotations can also be because high-productivity/low-cost producers enter the industry. Entry and innovations by high-productivity/low-cost firms further increase the uncertainty of predicting future market conditions.

Figure 9. Innovation with a counterclockwise shift in supply



xw

Schumpeterian entrepreneurs face numerous uncertainties that complicate their decisions. As Simon (1989) writes, economists' focus on allocation rather than innovation often leads to wrong conclusions, such as in Hotelling's (1931) classic article on resource economics. Textbooks claiming producers are worse off when total revenue declines are misleading because producer surplus increases initially even when revenue declines. In competitive environments, entry and innovation always raise consumer and total surplus, but the effect of entry and innovation on producer surplus is ambiguous. Innovation and entry cause an increase in quantity and a reduction in marginal production cost, which favors producers, and innovation and entry reduce price, which harms producers. Entry and innovation that generate clockwise supply rotations cause producer surplus to increase at first and then decline. Producer surplus eventually decreases when clockwise supply rotations lead supply to be more elastic than demand, where the price-reducing effect of the innovation dominates the cost-reducing and quantity-enhancing effects. This paper illustrates the importance of focusing not only on allocation but also on reducing scarcity through innovation. Concentrating on profit maximization might not make sense in a world of uncertainty (Simon 1989; Alchian 1950).

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