Innovation, Parallel Shifts of Supply, and Welfare

John B. Horowitz[1], Michael A. Karls[2], Juan Sesmero[3] and T. Norman Van Cott[4]

Abstract

This article examines the impact of parallel supply shifts that cause supply to transition from elastic to inelastic on consumer, producer, and total surplus. We show that parallel rightward shifts of the supply curve cause consumer surplus and total surplus to increase unambiguously. On the other hand, producer surplus increases, reaches a maximum in the inelastic portion of both the demand and supply curves and then declines. This implies that innovations of this sort eventually result in consumers appropriating a higher share of total surplus. Finally, the maximum points for various producer surplus curves fall on a line which begins at the highest point of the total revenue curve and ends at the lower right corner of the total revenue curve.

Key words: *innovation, parallel shift, producer surplus, consumer surplus, supply elasticity*

JEL codes: *A1-General Economics, D2-Production and Organizations, D6: Welfare Economics, O3-Technological Change*

Introduction

Miller et al. (1988) found that with elastic supply curves, producer surplus (*PS*) always increases when there is a parallel shift of the supply curve. However, Karagiannis and Furtan (2002) argued that assuming elastic supply curves greatly limits the application of Miller et al.'s (1988) work because there are many goods with inelastic supply curves. Karagiannis and Furtan (2002) found that for inelastic supply curves, *PS* decreases whenever the sum of the absolute values of the supply and demand elasticities is less than one.

Neither Miller et al. (1988) nor Karagiannis and Furtan (2002) considered the effect of parallel supply shifts on consumer surplus (*CS*) and total surplus (*TS*). We extend their analysis by looking at the impact of parallel supply shifts on *CS* and *TS*. We also extend their analysis by considering how *CS*, *PS* and *TS* change as supply transitions from elastic to inelastic.

[1] Associate Professor of Economics, Department of Economics, Ball State University, Muncie, IN 47306, jhorowitz@bsu.edu, 765-285-1436, 765-285-4313 (fax)

[2] Professor of Mathematical Science, Department of Mathematical Sciences, Ball State University, Muncie, IN 47306, mkarls@bsu.edu, 765-285-8656, (fax) 765-285-1721

[3] Assistant Professor of Agricultural Economics, Department of Agricultural Economics, Purdue University, West Lafayette, IN, jsesmero@purdue.edu, 765-494-7545

[4] Professor of Economics, Department of Economics, Ball State University, Muncie, IN 47306, tvancott@bsu.edu, 765-285-5370, 765-285-4313 (fax)

We show that parallel rightward shifts of supply cause *CS* and *TS* to increase unambiguously. On the other hand, *PS* increases, reaches a maximum in the inelastic portion of both the demand and supply curves and then declines. We also show that when there are parallel shifts of a linear supply curve, the maximum point for each producer surplus curve falls on the same line which begins at the highest point of the total revenue (*TR*) curve and ends at the lower right corner of the *TR* curve.

Parallel Shifts of Supply

Demand and supply schedules are:

(1) $P_D = a - bQ$

(2) $P_S = c + eQ$

P_D is the demand price, P_S is the supply price, a is the demand intercept, c is the supply intercept, b is the demand slope ($b>0$), and e is the supply slope. The quantity Q where $P_D=P_S$ is:

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

The elasticity of supply is elastic when $c>0$ and it is inelastic when $c<0$. We assume $P_S \geq 0$.

Note that when supply schedules are perfectly inelastic, *PS*=*TR*. On the other hand, when supply curves are perfectly elastic, *PS*=*0*.

If all producers improved their productivity equally there would be a parallel rightward shift of the supply curve. This would reduce c with e remaining constant. In agriculture, parallel shifts of the supply curve are caused by technological advances that increase yields in all types of land (Tollenaar et al. 2002).

PS for an elastic supply schedule is $PS_E = \frac{1}{2}(P-c)Q$. Equation 4 is found by substituting equation (2) for P and equation (3) for Q into PS_E.

(4) $$PS_E = \frac{1}{2}e\left(\frac{a-c}{e+b}\right)^2$$

Parallel shifts to the right reduce c. Differentiating (4) with respect to c yields:

(5) $$\frac{dPS_E}{dc} = -\frac{e}{e+b}Q.$$

Equation 5 is negative which implies a decrease in c increases producer surplus (Miller et al. 1988).

Now consider inelastic supply curves where $c<0$. To calculate *PS* with an inelastic supply curve, we find the difference between the price and the supply curve and subtract the area of the triangle that is below zero.[5] Figure 1 illustrates how parallel shifts affect *PS* where *D* is the demand curve and S_1 is an inelastic ($c<0$) supply curve. *PS* for supply curve S_2 is area P_2BE0 which is area P_2BC_2 minus area $0EC_2$.

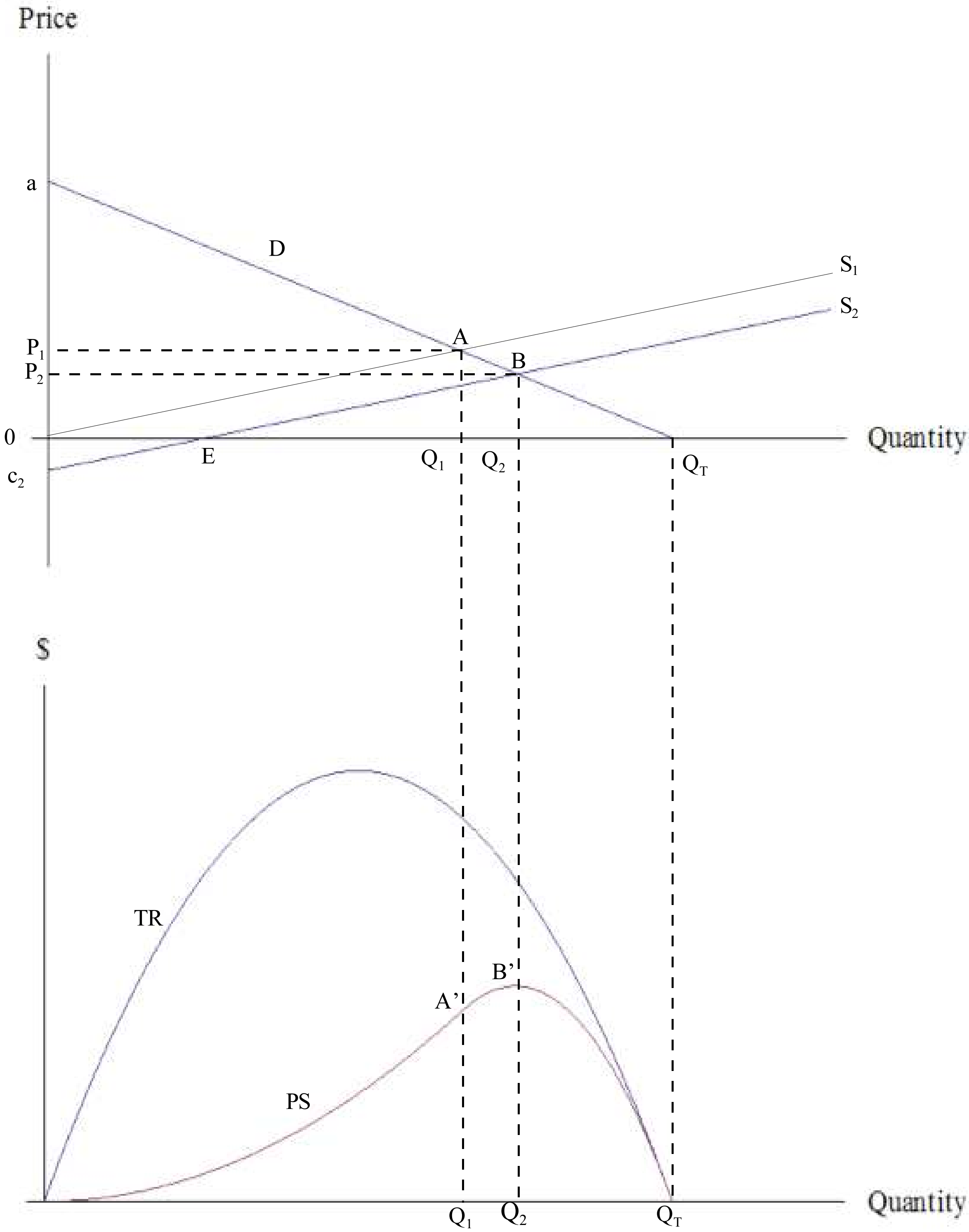

***Figure 1**: PS with parallel shifts of supply*

[5] In Figure 1, the equation for the demand curve is $P_D = 10–.5Q$ and the equations for the supply curves are $P_S = c+0.25Q$.

More formally, PS with inelastic supply, PS_I, is:

$$(6)\qquad PS_I = \frac{1}{2}\left[-\frac{c^2}{e} + e\left(\frac{a-c}{e+b}\right)^2 \right].$$

Differentiating (7) with respect to c, we obtain:

$$(7)\qquad \frac{dPS}{dc} = -\frac{c}{e} - eQ\left(\frac{1}{e+b}\right).$$

The sign in equation 7 is indeterminate—the first term is positive since $c<0$ and the second term is negative. Karagiannis and Furtan (2002) found that when there are parallel shifts of linear inelastic supply curves, PS increases when the sum of the absolute values of the supply and demand elasticities at the pre-innovation equilibrium is greater than 1. PS remains unchanged when the sum of the absolute values of the elasticities is equal to one and decreases when the sum of the absolute values is less than 1.

The lower portion of Figure 1 illustrates PS and TR for parallel shifts of an infinite number of supply curves where c decreases while e remains constant. When the elasticity of supply is elastic ($c>0$), PS_E increases at an increasing rate from the origin to Q_1 where $c=0$ (point A' on curve PS). When supply is inelastic ($c<0$), PS increases at a decreasing rate between Q_1 and Q_2, reaching a maximum at Q_2 (point B' on curve PS) and then decreases between Q_2 and Q_T.

3. Maximum Producer Surplus

Figure 2 shows that when there are parallel shifts of a linear supply curve, the maximum points on each PS curve lie along a line that begins at the highest point of the TR curve and ends at the lower right corner of the TR curve. As in Figure 1, the PS curves in Figure 2 show how parallel shifts of linear supply curves affect PS. The difference between Figure 2 and Figure 1 is that the bottom portion of Figure 2 includes more than one PS curve and the top portion only shows the supply curve that corresponds to the maximum point on each PS curve. For example, PS_2 in the bottom portion of Figure 2 is the same curve as PS in Figure 1 and S_2 in upper portion of Figure 2, is the supply curve that corresponds to the highest level of producer surplus along PS_2.

Though c varies with e constant for each PS curve in the lower portion of Figure 2, different values of e generate different PS curves. The smaller e is the more elastic the supply curve. When $e=0$, supply is perfectly elastic and there is no unique maximum point for PS since the PS curve will be along the x-axis. At a zero price, the quantity demanded will be Q_T.

Higher values for e generate more inelastic supply curves and parallel shifts of these more inelastic supply curves (i.e. c varies with e constant) generate higher PS curves. When supply is perfectly inelastic all revenue is PS. The maximum point for PS will be at the maximum point of TR (F' in Figure 2). The supply curve S_1 is more elastic than S_2 and PS curve PS_1 is lower than PS_2. Point C' shows the maximum PS along PS_0 and D' the maximum PS along PS_2.[6]

---

[6] PS_0 shows the schedule of producer surpluses when $e=0.07$, PS_1 is when $e=0.25$, PS_2 is when $e=0.7$, and PS_3 is when $e=1.5$.

To prove that when there are parallel shifts of a linear supply curve, the maximum points for each *PS* curve fall on the same line, we see that for any given choice of $e>0$, from equations (4) and (6), the corresponding *PS* curve is nonnegative with continuous first derivative for c greater than $-ae/b$. Setting the right hand sides of equations (5) and (7) equal to zero, and using equation (3) for Q, we find that *PS* has zero slope at $c = a$ and

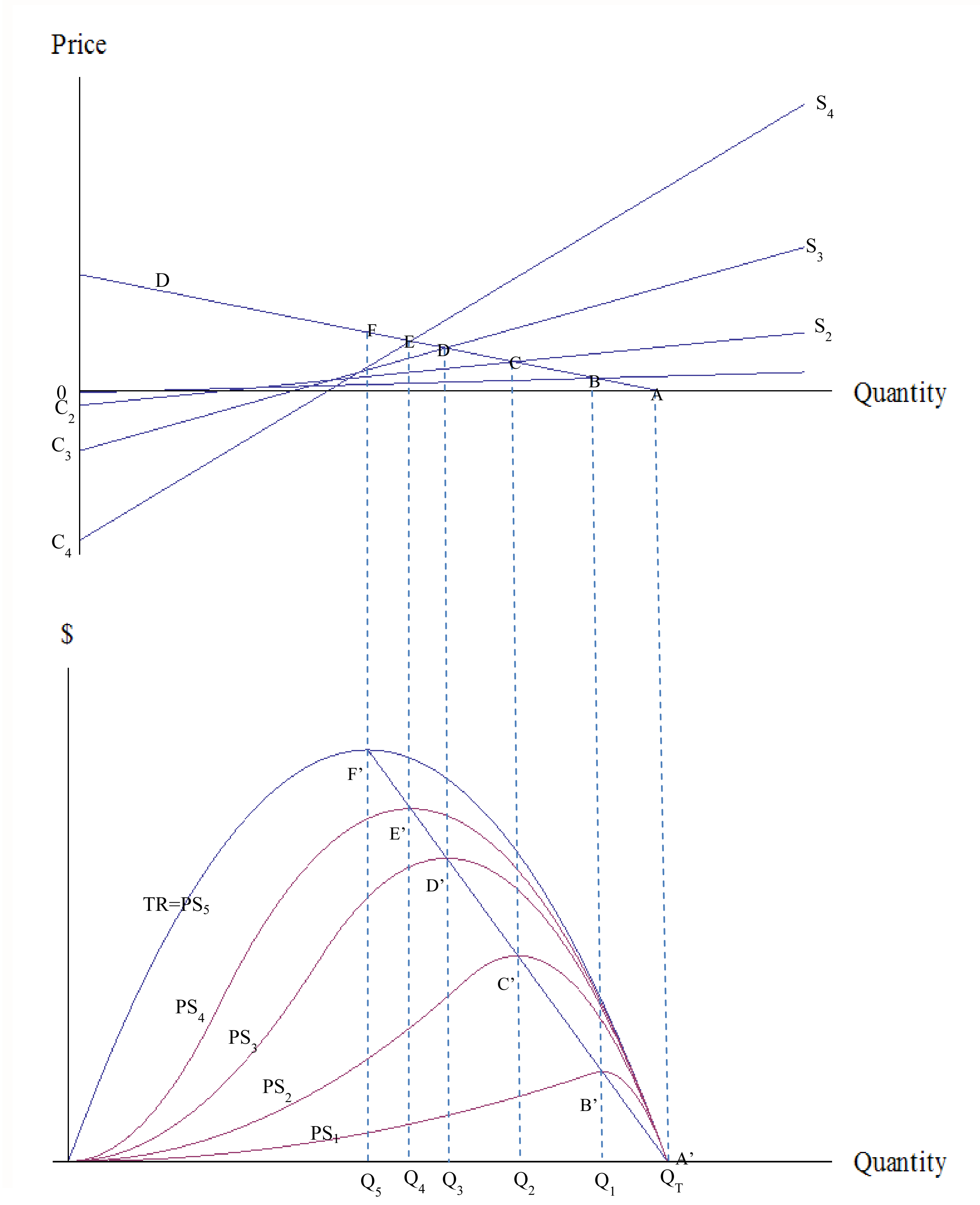

Figure 2: *Maximum points on PS curves lie along a straight line when there are parallel shifts of supply*

(8) $$c = -\frac{ae^2}{b(b+2e)} =: c(e)$$

It follows that the maximum *PS* on this *c*–interval occurs when we choose the *c*–value given by equation (8). Substituting *c(e)* from (8) for c in (3) and (7) yields an expression for the maximum point on the producer surplus curve corresponding to a given *e*–value:

(9) $$\left(Q\max(e),\, PS\max(e)\right) = \left(\frac{a-c(e)}{e+b},\ \frac{1}{2}\left[-\frac{c^2}{e} + e\left(\frac{a-c(e)}{e+b}\right)^2\right]\right) = $$
$$= \left(\frac{a(b+e)}{b(b+2e)},\ \frac{a^2 e}{2b^2+4be}\right).$$

To show that the set of maximum points $\{(Q\max(e),\, PS\max(e))\}$ we get from the *PS* curves as *e* varies through all positive real numbers all lie on the same line, choose any two such points, say $(Q\max(e1),\, PS\max(e1))$ and $(Q\max(e2),\, PS\max(e2))$, for $e1>0$ and $e2>0$. Then the slope of the line through these two points is

(10) $$\frac{PS\max(e1) - PS\max(e2)}{Q\max(e1) - Q\max(e2)} = \frac{\dfrac{a^2 e1}{2b^2+4be1} - \dfrac{a^2 e2}{2b^2+4be2}}{\dfrac{a(b+e1)}{b(b+2e1)} - \dfrac{a(b+e2)}{b(b+2e2)}} = -\frac{a}{2}.$$

Using the point slope form for the line through these two points, if the set of points $\{(Q\max(e),\, PS\max(e))\}$ are all on the same line, then for any *e>0*, the point $((Q\max(e),\, PS\max(e))$ should satisfy the equation

(11) $$PS\max(e) = -\frac{a}{2}[Q\max(e) - Q\max(e1)] + PS\max(e1)$$

Note that the slope in equation (11) is from (10). Substituting the values for PSmax and QSmax from (9), we see that (11) becomes

(12) $$\frac{a^2 e}{2b^2+4be} = -\frac{a}{2}\left[\frac{a(b+e)}{b(b+2e)} - \frac{a(b+e1)}{b(b+2e1)}\right] + \frac{a^2 e}{2b^2+4be}$$

and simplifying the right hand side of (12), we find that

(13) $$\frac{a^2 e}{4b^2+4be} = \frac{a^2 e}{2b^2+4be}$$

It follows from (13) that the points $\{(Q\max(e),\, PS\max(e)\}$ for positive *e*-values lie on the same line.

4. Total Surplus

Figure 3 depicts various *PS* and *TS* curves which are generated by changing *e*. For *CS*, there is only one curve because changes in *e* don't change its position. Movements along all of the curves are caused by changes in *c* (parallel shifts in the supply curve).

Since $TS=CS+PS$, when supply is perfectly elastic $e=0$, $PS=0$ so $CS=PS$ and *CS* and *TS* reach a maximum when the price is zero and the output is Q_T.

As mentioned above, greater values for *e* generate more inelastic supply curves and parallel shifts of these more inelastic supply curves generate higher *PS* curves. When supply is perfectly inelastic all revenue is *PS* and the *TS* curve is TS_5 in Figure 3.

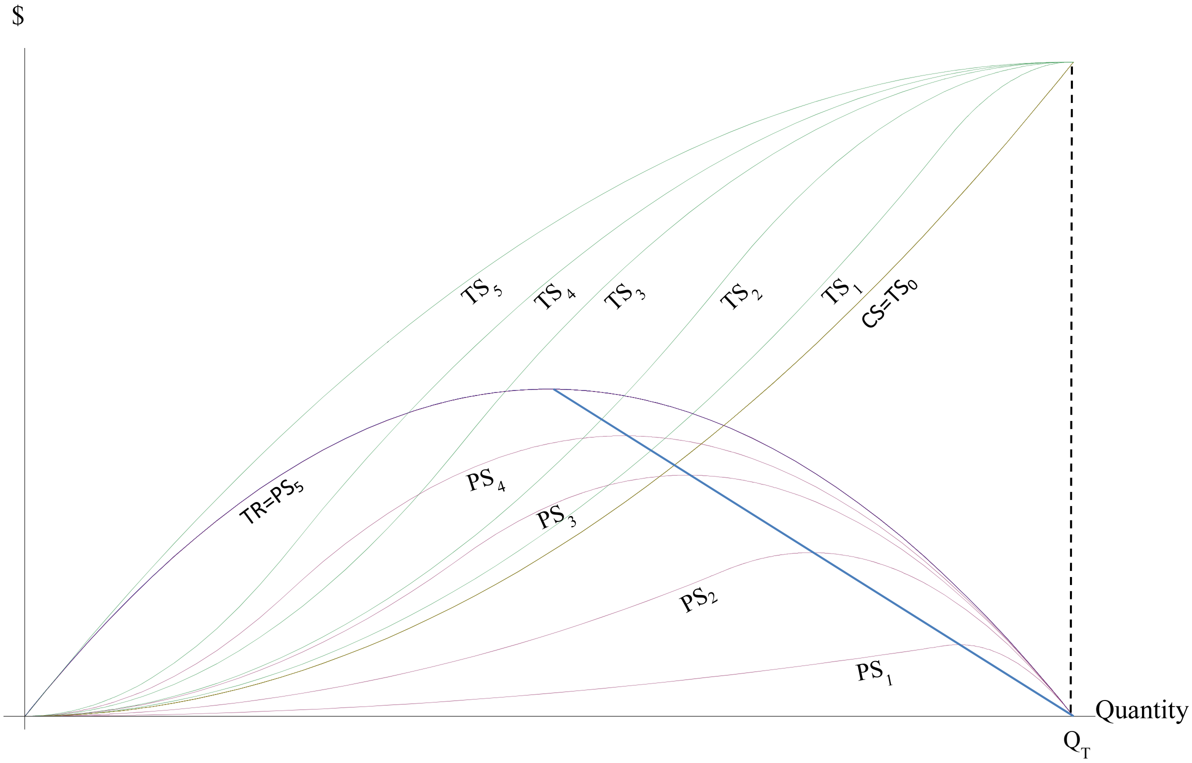

Figure 3: *CS, PS, and TS when there are parallel shifts of supply.*

For PS_1-PS_4, *TS* increases at an increasing rate up to when the supply is unit elastic then increases at a decreasing rate until the maximum *TS* occurs at Q_T. At every level of output between 0 and Q_T, *CS* always increases at an increasing rate. For all *PS* curves, *TS* and *CS* are maximized at Q_T. At Q_T, the good is not scarce so people can get all they want for free and $CS=TS$.

Therefore, though innovations causing parallel shifts in the supply curve will at some point reduce *PS*, *TS* always increases because the increases in *CS* are large enough to more than compensate for the fall in *PS*. Innovations therefore not only have efficiency implications (i.e. increasing total surplus) but also distributional implications. Innovations that cause parallel shifts of the supply curve will eventually increase the share of *TS* received by consumers.

5. Conclusion

Production innovations increase or decrease revenues depending on whether demand is elastic or inelastic.[7] However, these same innovations always increase consumer surplus and total surplus.

When the supply curve has a parallel shift, the maximum points of the producer surplus curves are along a straight line. This implies that reductions in the elasticity of supply increase producer surplus but shrink the range of outputs for which parallel-shifting innovations increase producer surplus. The curve that contains the maximum points of producer surplus starts at zero with a zero producer surplus and ends with producer surplus equal to total revenue when the supply curve is perfectly inelastic.

Karagianis and Furtan (2002 p. 10)) state that the social returns from research "…are greater when producers do not lose." However, we show that total surplus increases as the price decreases and the largest total surplus is when the price of the good is zero with no producer surplus and only consumer surplus.

Our results suggest that innovations causing parallel shifts of the supply curve may have distributional implications. This result is directly relevant to a range of industry situations such as technological innovations in the ethanol vertical supply chain (Karmarkar-Deshmukh and Pray 2009). Our results suggest that eventually rightward shifts in the supply of ethanol brought about by innovations in corn production and processing are more likely to benefit consumers at the pump rather than corn growers or gasoline companies.

Acknowledgements

The authors appreciate the comments of Cecil E. Bohanon, James E. McClure, and Cornelia A. Van Cott

References

Chryssochoidis, George M. (2003) "Factors affecting product innovations: A literature review," *Agricultural Economics Review*, 4, 47-62.

Karagiannis, G. and W. H. Furtan, (2002) "The Effects of Supply Shifts on Producers' Surplus: The Case of Inelastic Linear Supply Curves," *Agricultural Economics Review*, 3, 1, 5-11.

Karmarkar-Deshmukh, R. and C. E. Pray (2009) Private sector innovation in biofuels in the United States: Induced by prices or policies? *AgBioForum,* 12, 141-148.

Miller, Gay Y., Joseph M. Rosenblatt and Leroy J. Hushak, (1988) "The effects of Supply Shifts on Producers' Surplus," *American Journal of Agricultural Economics*, 70, 4, 886-891.

Tollenaar, M., and E. A. Lee, (2002) "Yield potential, yield stability and stress tolerance in maize," *Field Crops Research*, 75, 161-169.

Xu, Pei and Zhigang Wang, (2012) "Factors Affect Chinese Producers' Adoption of a New Production Technology: Survey Results from Chinese Fruits Producers," Agricultural Economics Review, 13, 5-20.

[7] Regarding determinants of these innovations Chryssochoidis (2003) discusses factors that affect product innovations and Xu and Wang (2012) discuss factors that affect producers' adoption of the new technologies.