Quality Responses to Agricultural Policies

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Abstract

Most policy analyses are conducted using a model of a single market for a homogeneous commodity. Usually, the commodity of interest is not truly homogeneous, but is treated as such for the sake of simplicity. In doing so, analysts are implicitly assuming that a single-market model of a homogeneous product closely approximates true policy effects. This paper explores the implications of this assumption. The effects of the homogeneity assumption are shown for the simple case of a product available in two qualities, when market-distorting policies are introduced. It is shown that, for plausible parameter values, ignoring quality responses can have substantial impacts on the estimated welfare effects of stereotypical commodity price support policies. In addition, for a given transfer to producers, a model that incorporates quality responses to policies will imply different settings for policy instruments than a model of a homogeneous commodity, and in some cases, different instruments. For some transfers, the inclusion of quality responses will switch the transfer efficiency ranking of policies.

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The typical analysis of agricultural policies assumes that the commodity of interest is homogeneous, and that the nature of the commodity does not change as a result of the implementation of the policy. In some cases, these may be appropriate assumptions. In a number of instances, though, commodities are quite heterogeneous. Most agricultural commodities have several economically important characteristics, such as their agronomic variety, producer, geographic region, appearance, distance from market, size, ripeness, freshness, uniformity, grade, packaging, and the time of year when they are available, all of which may vary over different units of production. Each of these objectively-defined characteristics can be thought of as a dimension of product heterogeneity, some of which are defined as discrete categories, while others are defined as varying continuously. While most economists recognize that commodities are not perfectly homogeneous, the assumption is rarely mentioned or justified in studies of commodity policy.

It appears that the assumption of product homogeneity may be based on the belief that quality effects are not important, so that modeling the market for a commodity as if it were homogeneous closely approximates reality. However, representing a commodity as if it were homogeneous fails to account for changes in the distribution of quality (or average quality) that may occur as a result of the implementation of policy. Alchian and Allen (1964) and Barzel (1976) make persuasive theoretical arguments for the existence of such quality changes in response to per unit costs or taxes. In addition, many instances may be found where quality has responded to policy. Nevertheless, quality responses have yet to be incorporated formally into the analysis of agricultural commodity policy. Rather, economists have presumed implicitly that explicitly modeling quality responses to policy is unnecessary. However, it is impossible to determine how closely a model of a homogeneous good approximates the actual policy impacts until a more complete model has been developed and implemented.

This paper explores the implications of inappropriately assuming product homogeneity for agricultural policy analysis. To do this, the effects of the product homogeneity assumption are illustrated when the product of interest is actually available in two qualities (low and high) and market-distorting policies are introduced. A model of two related markets is specified, which is sufficient to allow for policy-induced quality responses. To provide the contrast, a single-market model is specified in which the commodity of interest is treated as if it were homogeneous (i.e., average quality is constant). Quota policies and target-price policies are introduced into each of the two models. The estimated welfare effects of the policies from the single-market model of a homogeneous commodity are compared with those from the two-market model that allows for quality responses. These qualitative comparisons show the direction of error in estimating true policy effects under the false assumption of product homogeneity. It is also shown quantitatively that allowing for quality responses can substantially alter the estimated welfare effects of the policies, and the implied setting for a policy instrument necessary to achieve a given policy goal. Furthermore, in some cases, quality responses may even change the optimal policy instrument choice.

1 Quality Responses

Work by Alchian and Allen (1964) and Barzel (1976) suggests that the implementation of certain types of policies will alter the distribution of units across qualities. The Alchian and Allen theorem postulates the effects of transportation costs on the relative consumption of high- and low-quality goods. The original example given by Alchian and Allen (1964) concerned "good" and "bad" grapes grown in California, with good grapes selling for a higher price than bad grapes. They noted that the cost of transporting grapes to, say, New York is the same for all shipments of grapes, regardless of their quality. From an individual consumer's perspective, prices are fixed so that the price of each quality of grapes increases by the same amount for consumers in New York. Thus, good grapes become *relatively* cheaper for a consumer in New York, and hence, a New Yorker will consume a larger proportion of good grapes relative to a person in California with identical preferences.

The typical per unit cost introduced to produce the Alchian-Allen effect is a transportation cost. The hypothesized increase in the consumption share of high-quality goods could occur as a result of many other types of per unit costs. Umbeck (1980) discussed the nature of these costs, and stated that in order for a per unit cost to generate the Alchian-Allen result, the cost must not change the good itself, and it must not have any inherent economic value in and of itself–i.e., it acts just like a per unit tax. Like a tax policy, a quota policy creates a wedge between the consumer and producer prices, the price difference being per unit quota rent. From an individual producer's perspective, quota rent is a cost that meets the criteria specified by Umbeck (1980). As a result, the quota policy would be expected to have the same kind of quality distorting effect as a per unit tax. Conversely, a per unit subsidy would distort relative consumption in favor of the lower-quality product.

Because these analyses of Alchian-Allen effects are conducted at the individual consumer level, prices are exogenous, and the entire cost or tax is borne by the consumer. When either transportation costs or per-unit taxes are introduced at the market level, these costs are shared by consumers and producers, and theory has had little to say about the relative changes in production and consumption of low- and high-quality commodities. Using a theoretical equilibrium displacement model of two commodities, James (1999) found a relative increase in consumption and production of the higher-quality commodity in response to a per unit tax, at the market level. Bertonazzi, Maloney, and McCormick (1993) note that the Alchian-Allen effect is a convincing empirical regularity at the market level.

Barzel (1976) addressed a similar phenomenon at the market level in his alternative approach to taxation. Barzel noted that every commodity is more or less a bundle of characteristics. Because an ad valorem tax is applied to the commodity's entire value, it essentially taxes all of its characteristics. In contrast, if a per unit tax is imposed, the tax statute will use a subset of characteristics to define the commodity, since an exhaustive description is either impossible or very costly. As a result, the per unit tax actually taxes those characteristics used to define the commodity. In maximizing their profits subject to the tax, producers may alter the characteristics included in their units of production in order to minimize their costs of the per unit tax. Barzel (1976) showed that a predictable outcome is a decrease in the quantity of the defining characteristics (specified in the tax statute), and an increase in the additional characteristics (per unit), which are not subject to the tax because they are not specified in the statute.

While Barzel's (1976) analysis was conducted at the market level, his approach does not lend itself to empirical application. He defined a single demand function for a single characteristic of a commodity. This approach assumes that the single characteristic completely defines the quality of the commodity of interest, and that consumers are indifferent to how that characteristic is packaged into physical units (i.e., a bundle of n physical units, each of which has one unit of the characteristic, is a perfect substitute for a single physical unit with n units of the characteristic). This paper allows for a more general definition of quality by adopting a multi-market framework. The commodity of interest is assumed to be available in two qualities, low and high, which are related in consumption and production. The relationship between the markets allows for some substitution (not necessarily perfect substitution) between the two qualities, in both demand and supply.

2 The Two-Market Model

To represent demand and supply conditions in the two-market model, linear supply and demand functions are specified for each market. :

$$Q_L^D = a + bP_L^D + cP_H^D \tag{1}$$

$$Q_L^S = d + eP_L^S + fP_H^S \tag{2}$$

$$Q_H^D = A + BP_L^D + CP_H^D \tag{3}$$

$$Q_H^S = D + EP_L^S + FP_H^S \tag{4}$$

where subscripts L and H are used to denote prices or quantities in the low- and high-quality markets, respectively, and superscripts D and S denote prices or quantities defined along a demand or supply curve.[1] Each slope and intercept parameter may be expressed in terms of prices, quantities, and elasticities at the initial equilibrium. As a result, the supply and demand functions can also be specified as:

$$Q_L^D = Q_L^0(1 - \eta_{LL} - \eta_{LH}) + \eta_{LL}\frac{Q_L^0}{P_L^0}P_L^D + \eta_{LH}\frac{Q_L^0}{P_H^0}P_H^D \quad (5)$$

$$Q_L^S = Q_L^0(1 - \epsilon_{LL} - \epsilon_{LH}) + \epsilon_{LL}\frac{Q_L^0}{P_L^0}P_L^S + \epsilon_{LH}\frac{Q_L^0}{P_H^0}P_H^S \quad (6)$$

$$Q_H^D = Q_H^0(1 - \eta_{HL} - \eta_{HH}) + \eta_{HL}\frac{Q_H^0}{P_L^0}P_L^D + \eta_{HH}\frac{Q_H^0}{P_H^0}P_H^D \quad (7)$$

$$Q_H^S = Q_H^0(1 - \epsilon_{HL} - \epsilon_{HH}) + \epsilon_{HL}\frac{Q_H^0}{P_L^0}P_L^S + \epsilon_{HH}\frac{Q_H^0}{P_H^0}P_H^S \quad (8)$$

where superscripts 0 indicate the prices and quantities at the initial, undistorted, equilibrium, η_{ij} is the elasticity of demand for quality i with respect to the price of quality j, and ϵ_{ij} is the elasticity of supply of quality i with respect to the price of quality j.

In order to reduce the number of parameters and to clarify the implications of assuming a homogeneous commodity, the price elasticities in equations (5) through (8) are decomposed into scale and substitution effects by invoking a separability assumption. This approach was taken by Armington (1969) in his model of traded products differentiated by country of origin. Under the assumption that low- and high-quality varieties of the same basic commodity comprise a weakly separable group with equal expenditure elasticities (i.e., homothetic separability), their own- and cross-price elasticities of demand can be expressed

[1] James (1999) solved for the effects of taxes in a more general model without assuming a particular functional form. The linear model is used here because an explicit functional form is needed for the welfare analysis and because the policies involve discontinuities. Many of the qualitative results demonstrated here for the case of linear functional forms may be derived from the more general specification.

as:

$$\eta_{LL} = s_L\eta - s_H\sigma \tag{9}$$

$$\eta_{LH} = s_H(\eta + \sigma) \tag{10}$$

$$\eta_{HL} = s_L(\eta + \sigma) \tag{11}$$

$$\eta_{HH} = s_H\eta - s_L\sigma \tag{12}$$

where $s_i = \frac{P_iQ_i}{PQ}$ is the value share of commodity i (the absence of subscripts indicates an aggregate price or quantity). Here, η is the overall elasticity of demand, defined as the elasticity of demand for the aggregate quantity with respect to the aggregate price ($\eta < 0$), and σ is the elasticity of substitution between low- and high-quality commodities ($\sigma > 0$).

The own- and cross-price elasticities of supply can be expressed similarly as:

$$\epsilon_{LL} = s_L\epsilon - s_H\tau \tag{13}$$

$$\epsilon_{LH} = s_H(\epsilon + \tau) \tag{14}$$

$$\epsilon_{HL} = s_L(\epsilon + \tau) \tag{15}$$

$$\epsilon_{HH} = s_H\epsilon - s_L\tau \tag{16}$$

where ϵ is the overall elasticity of supply, which is defined as the elasticity of the aggregate quantity supplied with respect to changes in the aggregate price ($\epsilon > 0$), and τ is the elasticity of transformation between low- and high-qualities in the production process ($\tau < 0$).

The relationship between these elasticities and those from a single-market representation is most apparent in the context of a two-stage budgeting process. If, as assumed here, preferences are weakly separable and the price index for each group is invariant to changes in income, then consumption decisions may be represented in two stages. In the first stage, total expenditure is allocated among groups of commodities, based on aggregate prices (i.e., price indexes) for the commodity groups. In the second stage, expenditure for each group is allocated among the individual commodities, based on their relative prices. The two components of the price elasticities can be interpreted as first-stage and second-stage responses to a change in one of the prices. For example, a change in the price of the low-quality commodity will change the price index for the commodity group, and will change the expenditure on that group (the scale effect). The change in the price of the low-quality good also alters the relative prices of the low- and high-quality varieties, and will therefore change the relative consumption of the two qualities (the substitution effect). An aggregate analysis would only account for the changes in the aggregate price, and would ignore any change in the relative prices of commodities within the group. As a result, only the scale effects from the first stage of the budgeting process would be evaluated, and the substitution effects from the second stage would be omitted. Thus, treating a group of commodities as if it were a single commodity is equivalent to setting those substitution effects equal to zero (i.e., $\sigma = 0$ and $\tau = 0$).

3 A Constant Quality Aggregate

Because the goal of this analysis is to contrast correct measures of policy incidence with those typically obtained, some reasonable representation of the conventional single-market specification must be introduced. Here, the aggregate quantity is defined as a simple sum of the quantities observed in each market, and the aggregate price is defined as the average unit value.[2] Thus,

$$Q^D = Q_L^D + Q_H^D \tag{17}$$

$$Q^S = Q_L^S + Q_H^S \tag{18}$$

$$P^D = \frac{Q_L^D}{Q^D} P_L^D + \frac{Q_H^D}{Q^D} P_H^D \tag{19}$$

$$P^S = \frac{Q_L^S}{Q^S} P_L^S + \frac{Q_H^S}{Q^S} P_H^S \tag{20}$$

In order to obtain supply and demand functions for the aggregate market, a further assumption is made about the composition of the aggregate quantity. Using the quantity share of the high-quality variety, Q_H/Q, as a measure of average quality, average quality is held constant in the representation of the aggregate market by assuming that quantity shares remain constant at their initial levels. In order to derive aggregate demand and supply equations, the quantities in the low- and high-quality markets are varied together, holding the proportions fixed, implying specific price changes in each market. From those quality-specific price changes, the new aggregate price corresponding to the new aggregate quantity is calculated, using the definitions provided above. Using this method and the elasticity decompositions described in section 2, the demand and supply functions in the aggregate market are defined as:

$$Q^D = Q^0(1-\eta) + \eta \frac{Q^0}{P^0} P^D \tag{21}$$

[2] An informal survey of agricultural economists who have conducted empirical analyses of commodity policies indicated that the use of a simple sum for a quantity aggregate is common. The typical aggregate price used is either an average unit value (total value divided by total physical quantity) or a representative price (e.g., an average price of a particular variety or grade at a particular location). Here, average unit value is used so that total expenditure in the aggregate market is equal to the sum of the expenditures in the quality-specific markets. The results presented here would not be altered by the use of some other price index, provided that it be invariant to income.

$$Q^S = Q^0(1-\epsilon) + \epsilon \frac{Q^0}{P^0} P^S \tag{22}$$

Notably, these functions are of the same form as the quality-specific demand functions in equations (5) through (8), but include only the scale-effect portion of the elasticities, with no allowance for substitution between the two qualities. The result is a typical representation of the aggregate market that is meaningfully related to the disaggregated representation in equations (5) through (8).

4 Initializing the Model and Introducing Policies

To summarize, the two-market model consists of equations (5) through (8), where the elasticity terms are as defined in equations (9) through (12) and (13) through (16). The single-market "equivalent" with the fixed proportions (constant quality) restriction embedded consists of equations (21) and (22). These models were initialized using the prices and quantities listed in table 1. The initial aggregate quantity is divided equally between the low- and high-quality markets, for an average quality measure (Q_H/Q) of 0.5. The price premium for the high-quality variety, defined as the relative price of high- and low-quality varieties (i.e., P_H/P_L) is 3.0 at the initial equilibrium. How reasonable is this quality premium? Table 2 shows price ranges over qualities for some commodities. While the price ranges presented here cannot be interpreted exactly in terms of the high- and low-quality prices from the model, they do indicate that the prices of agricultural commodities typically vary substantially over qualities.

The initial values for the four elasticity parameters (η, σ, ϵ, and τ), and the resulting

Table 1: Initial Values for Prices and Quantities in Low-Quality, High-Quality, and Aggregate Markets

	Low-Quality Market	High-Quality Market	Aggregate Market
Quantity	0.50	0.50	1.00
Quantity-share	0.50	0.50	1.00
Price	0.50	1.50	1.00
Value-Share	0.25	0.75	1.00

own- and cross-price elasticities of demand and supply are in table 3. For these parameter values, the scale effect in demand is smaller than that in supply (i.e., $\mid \eta \mid < \epsilon$), so that, in the aggregate market, supply is more elastic than demand. However, the two qualities are more substitutable in demand than they are in supply (i.e., $\sigma > \mid \tau \mid$). Finally, the substitution effect outweighs the scale effect on the demand side (i.e., $\sigma > \mid \eta \mid$), so that the two qualities are substitutes in demand, whereas they are complements in supply (i.e., $\mid \tau \mid < \epsilon$). The relationships implied by these parameter values seem reasonable for a number of commodities, but different particular values will be appropriate for different commodities.

Wheat has been treated as a differentiated product in many studies and provides a good (and important) example. Sumner, Alston, and Gray (1994) reviewed more than ten studies of wheat markets that have specified and estimated the types of Armington elasticity parameters used here. They found that estimates of the overall demand elasticity for wheat are quite small in magnitude, generally between -0.10 and -0.30, somewhat lower than the -0.5 used here as representing a "typical" agricultural commodity. The range of estimated values for the elasticity of substitution for wheat from different countries is much larger. While the typical value used for the elasticity of substitution is about 3.0, estimates

Table 2: Price Ranges for Selected Commodities

Commodity	Price Units	Price of Low Quality	Price of High Quality	Price Ratio
Apples [a]	$ per carton	12.00	19.00	1.58
Cotton[b]	cents per pound	43.99	58.29	1.33
Eggs [c]	cents per dozen	47.18	70.94	1.50
Potatoes	$ per 50 pound carton	10.50	35.00	3.33
Russet[d]	$ per 50 pound carton	10.50	16.75	1.60
Round Red [e]	$ per 50 pound carton	13.00	35.00	2.69
Yukon Gold [f]	$ per 50 pound carton	15.75	35.00	2.22
Oranges [g]	$ per carton	14.00	37.00	2.64
Tobacco [h]	$ per pound	1.20	1.88	1.57
Wheat [i]	$ per bushel	2.50	3.04	1.22
Wool [j]	A$ per kilogram	3.86	9.88	2.56

Unless otherwise noted, prices are those for the San Francisco terminal market on August 23, 1999, obtained from the Agricultural Marketing Service, USDA.

[a] Low-quality price is for Washington Fancy Red Delicious apples, size 88 (number per carton). High-quality price is for Washington Extra Fancy Red Delicious apples, size 72.

[b] Prices are spot prices in the San Joaquin Valley of California for December 23, 1999. Low-quality price is for staple length 34, grade 51-5, and the high-quality price is for staple length 36, grade 21-2.

[c] Prices average prices on sales to volume buyers in twelve metro areas for the week ending September 3, 1999. Low-quality price is for medium, and high-quality price is for extra-large eggs.

[d] Low- and high-quality prices are for sizes 40 and 100, respectively.

[e] Low- and high-quality prices are for sizes A and small, respectively.

[f] Low- and high-quality prices are for sizes A and small, respectively.

[g] Low-quality price is for Shippers Choice Valencia oranges, size 113 (number per carton). High-quality price is for First Grade Valencia oranges, size 56.

[h] Prices are Season Auction bid averages for flue-cured tobacco in Raleigh, NC, as of November 12, 1999.

[i] Source: Kansas City Grain Market Review. Prices are cash prices in Kansas City on August 1, 1990. Low-quality price is for No. 4 soft red wheat, and high-quality price is for No. 1 hard wheat. These prices do not incorporate premia and discounts for protein, so the actual price range is larger than reflected here.

[j] Source: Australian Wool Exchange. Prices are quotes from the Australian Wool Exchange on December 16, 1999. Low- and high-quality prices correspond to 25 and 19 micron fiber diameter, respectively. A substantially wider range of quotes were available for wool of fiber diameter outside of this range, but this range covers those qualities for which there is an active futures market.

Table 3: Elasticity Parameters Used to Initialize Models

Demand $\eta = -0.5$ and $\sigma = 2.0$	Supply $\epsilon = 1.0$ and $\tau = -0.5$
$\eta_{LL} = -1.625$	$\epsilon_{LL} = 0.625$
$\eta_{LH} = 1.125$	$\epsilon_{LH} = 0.375$
$\eta_{HL} = 0.375$	$\epsilon_{HL} = 0.125$
$\eta_{HH} = -0.875$	$\epsilon_{HH} = 0.875$

of this parameter have varied widely in the literature, from 0.75 to values in excess of 25.0. Johnson (1971) found similar values for non-wheat commodities as well. These estimates will be sensitive to specification choices, specifically the extent to which the data has been disaggregated. As wheat (or any other commodity) is disaggregated into more groups, the wheat in any particular group will be more homogeneous, and the degree of substitutability among wheat within a group will increase. Alston et al. (1990) suggest that many estimates of the elasticity of substitution may be biased downward by more than 50 percent, due to the functional form restrictions implicit in Armington models.

Also reported in Sumner, Alston, and Gray (1994) is a review of several estimates of supply elasticities for wheat. They concluded that for the United States, an overall supply elasticity of wheat of 1.0 was reasonable, and speculated that the elasticity of transformation between milling, feed, and durum wheats might be about -2.0. The supply elasticity of 1.0 used here is within the range of supply elasticities used in most studies of commodity markets. Based on the review conducted by Sumner, Alston, and Gray (1994) and other studies of commodity policies, it appears that the elasticity parameters used to initialize this model are quite reasonable. For some commodities or some levels of commodity aggregation, the values used here for the parameters measuring the substitution effects (σ and τ) may be small. However, as is shown in section 6, increasing these values increases the degree of quality responses to policies, and strengthens the main conclusions.

4.1 Production Quota

Next, a production quota is introduced into the single-market model and the two-market model and varied between 1.0, the initial quantity, and zero. In the single-market model, this is done by setting the quantity produced and consumed equal to the quota, and allowing the consumer and producer prices to differ, the difference at the new (imposed) equilibrium quantity being the per unit quota rent. In the two-market model, the sum of low- and high-quality quantities, $Q_L + Q_H$, is restricted to the quota quantity. The allocation of the quota between the two markets is determined by imposing an arbitrage condition that equates quota rent per unit across the two markets (i.e., the quota is transferable). At each quota quantity, changes in consumer surplus (CS), producer surplus (PS), quota rent (QR), and net social surplus are calculated in each of the two models.

The quota-induced change in average quality is similar to that resulting from the imposition of a per unit tax. Because the per unit quota rent acts as a per unit tax, the proportional quantity reduction in the low-quality market is expected to be larger than that in the high-quality market, so that average quality increases as the quota is reduced. This is, in fact, what occurs in the two-market model, as can be seen in table 4. As the quota is reduced from the undistorted quantity of 1.0, the quantity of low-quality units produced and consumed decreases by a larger proportion than the quantity of high-quality units does. In fact, at some quota quantity (approximately 0.36 for the parameter values used here), production of the low-quality good falls to zero, and all of production is high quality. Thus, there is clearly a quality response to the imposition of a quota.

Table 4: Quantities of Each Quality and Average Quality, for Various Quota Quantities

Quota	Q_L	Q_H	Q_H/Q
1.00	0.50	0.50	0.50
0.90	0.42	0.48	0.53
0.80	0.34	0.46	0.57
0.70	0.26	0.44	0.62
0.60	0.19	0.41	0.69
0.50	0.11	0.39	0.79
0.40	0.03	0.37	0.93

What are the implications of the quality response for the evaluation of the welfare effects of the quota? The welfare effects of the quota policy are conveniently summarized in surplus transformation curves (STCs), as developed by Josling (1974) and popularized by Gardner (1983). The STCs in figure 1 plot the changes in consumer surplus along the horizontal axis and the corresponding changes in producer surplus (including quota rent) along the vertical axis. Movement from the origin to the left along the STCs indicates the reduction in CS and the increase in PS as the quota quantity is reduced. Only quotas greater than 0.36 are represented in figure 1, since further quota reductions caused the quantity in the low-quality market to drop to zero. This quota quantity is less than the monopolist's quantity that maximizes the sum of producer surplus and quota rent, so the exclusion of quotas less than 0.37 is not a cause for concern. The dashed line shows the tradeoff between producer and consumer welfare, as measured in the standard single-market model, while the solid line shows the same relationship for the two-market model that incorporates quality changes. Note that the quota quantity varies at different rates along the two STCs, as seen most clearly by the left-most points of the two curves, both of which correspond to a quota of 0.37.

The position of the STC for the two-market model below that of the single-market model indicates that a quota policy is actually a less efficient means of transferring income to producers than the single-market model would suggest. This result may seem counter-intuitive at first. Consumer losses from the quota should be smaller when the increased quality of production is incorporated. Further, why would producers alter the quality distribution of their production in response to the quota if doing so made them worse off?

Looking at the changes in the individual surplus measures helps to explain this result. As the quota is reduced, consumers are made worse off. However, because of the quota-induced increase in quality incorporated in the two-market model, the CS reduction is smaller than if the quality response were not taken into consideration, as in the single-market model. Thus, for a given quota, the actual reduction in CS *is* smaller than the conventional single-market model indicates, in keeping with intuition. A similar relationship holds for the changes in producer surplus (excluding quota rent). As the quota quantity decreases, producer surplus decreases in both models, but because of the quality increase, the reduction in producer surplus is actually smaller when quality responses are accounted for.

Since the quota-induced reductions in CS and PS are smaller with quality responses, what, then, accounts for the lower efficiency of the quota? Quota rent accounts for this difference. Figure 2 plots the quota rent earned for each quota quantity for the single-market and two-market models. At every quota quantity, quota rent from the single-market model overstates the true quota rent from the two-market model. The quota-rent maximizing allocation of the quota would reduce the quantity sold in each market by the same proportion, as in the single-market representation. Because the allocation of the quota allows for a larger proportional quantity reduction in the low-quality market than in the high-quality market, it is this reallocation of the quota that reduces the quota rent.

For the set of parameters considered here, the following can be said about the errors in estimating the welfare effects of a quota that arise from incorrectly assuming constant quality and using a single-market model rather than a true two-market representation. For a given quota quantity, the true loss to consumers and the true benefit to producers (including quota rent) are both smaller than the single-market model suggests. For a given quota quantity, the smaller increase in producer benefits is more than offset by the smaller loss to consumers, so that the deadweight loss (DWL) from the quota is smaller than indicated by the single-market model. So, for a given reduction in quantity, the actual DWL from a quota is smaller than a single-market model would suggest. In contrast, for a given transfer to producers, the actual DWL from a quota is larger than a single-market model would suggest (as shown in the STCs in figure 1).

4.2 Target-Price Policies

The other policy considered here is a target-price policy. When the commodity of interest is actually homogeneous, a single target price is adequate for defining such a policy. However, when the analysis is extended to consider the case of two qualities, the target-price policy requires further definition. One can imagine a target-price policy in which a single target price is offered, and the qualities of the commodity to which the target price applies are not specified. This policy is described below and referred to as the simple target-price policy. A less-distortionary target-price policy would recognize the different qualities of the commodity being supported, and would offer a different target price for each variety or quality. In this case, one can imagine target-price schemes as pairs of target prices, one for each quality.

There are many such target-price schemes. One possible scheme, referred to below as the constant price differential target-price scheme, increases the price of each quality by the same amount per unit relative to the initial (undistorted) quality-specific prices. An example would be to offer target prices for each quality that are \$0.25 above their pre-intervention prices (i.e., \$0.75 for low-quality and \$1.75 for high-quality). Maintaining the assumption of fixed quantity proportions in the aggregate market, the corresponding target price in the aggregate market would be \$1.25. Another type of target-price scheme would offer quality-specific target prices that maintain relative prices at their initial levels. For example, if the target price offered for low-quality were \$0.75, a 50 percent increase over the pre-intervention price of \$0.50, then the corresponding price offered in the high-quality market would be \$2.25, also a 50 percent increase. The corresponding target price in the aggregate market would then be 50 percent above the pre-intervention price in the aggregate market, \$1.50. This target-price scheme is referred to below as the constant relative price target scheme.

Table 5 shows the quality distortions for different prices under these three target-price schemes (recall that initial average quality is 0.50). Each scheme is defined as a set of two quality-specific target prices, and the values of those target prices are varied according to rules described above for each policy. The first column of table 5 lists the weighted average of the two target prices, as calculated for the aggregate market (i.e., assuming fixed proportions between low- and high-quality quantities). In the case of the simple target-price policy, the two quality-specific prices are equal, so they both equal the weighted average price in the first column. For the constant price differential policy, the undistorted prices in each quality-specific market are increased by the same increment, and the price in the first column refers to the weighted average of those two prices (assuming fixed proportions). For the constant relative price policy, the undistorted prices in each quality-specific market are increased by the same proportion, and, again, the price in the first column refers to the weighted average of those two prices.

Table 5: Average Quality for Three Target-Price Policies and Various Target Prices

Weighted Average of Quality-Specific Target Prices	Simple Target Price Q_H/Q	Constant Price Differential Q_H/Q	Constant Relative Price Q_H/Q
\$0.50	0.50	0.50	0.50
\$0.60	0.47	0.50	0.50
\$0.70	0.45	0.50	0.50
\$0.80	0.42	0.50	0.50
\$0.90	0.40	0.50	0.50
\$1.00	0.38	0.50	0.50
\$1.10	0.37	0.49	0.50
\$1.20	0.36	0.47	0.50
\$1.30	0.36	0.46	0.50

The changes in average quality shown in table 5 occur because of changes in the relative prices of the two goods. The simple target-price scheme alters relative prices, and fixes the producer price ratio at 1.0 when the target price binds in both markets. As a result of the decrease in the producer's quality premium, average quality decreases as the target price is increased. In contrast to the simple target-price policy that binds in at least one of the markets for weighted average target prices above \$0.50, the constant price differential and constant relative price schemes only bind for weighted average prices above the initial aggregate price of \$1.00. The constant price differential policy changes the relative prices of the two qualities, but does not fix them at 1.0. In this case, the reduction in average quality is mitigated relative to the simple target-price policy. Because the constant relative price policy does not distort the relative prices of the two qualities, there are no substitution effects, and no change in the average quality of production.

When the policy effects are compared between the single-market and two-market models, the differences will be larger, the larger are the distortions in relative prices and thus in average quality. The simple target-price policy will be used as an illustrative example of a target-price policy. Since it has the most distortionary impact on quality, this policy provides an upper bound on the error in the welfare measurement from ignoring quality responses (the lower bound being given by the constant relative price policy, in which there is no error). Most target-price schemes, in practice, will act as a simple target-price policy, at some level of aggregation.

Figure 3 shows the STCs for the simple target-price policy, as measured in the two-market model (solid line) and in the single-market model (dashed line). Like the quota, the target-price policy is a less efficient means of transferring income to producers than the single-market model indicates. Given the policy-induced *decrease* in quality, this result is a little more intuitive than it was for the quota. One aspect of this result that is a bit unexpected is that consumers actually benefit from a simple target-price policy more than indicated in the single-market model. It might seem that the gain to consumers would be smaller because of the decrease in quality. However, because the quantity responses to the target price are unrestricted, the consumer benefit from the increase in quantity offsets the consumer loss from the decrease in average quality.

In addition to the quantity responses, another factor contributes to the larger consumer benefit from the target-price policy when quality varies. Because the undistorted price in the low-quality market is lower than the undistorted price in the aggregate market, some target prices set below the undistorted equilibrium price in the aggregate market will confer benefits to consumers and producers. So, target prices between $0.50 and $1.00 (the undistorted prices in the low-quality and aggregate markets, respectively), benefit consumers and producers, while incurring taxpayer costs. These benefits and costs will not be reflected in the welfare measures from the single-market model, since only target prices above $1.00 bind in that market representation. Target prices above $1.00 but below $1.20 bind only in the low-quality market, and the high-quality market clears at a price above the target price. Target prices of approximately $1.20 and larger (for the parameters specified) bind in both the high- and low-quality markets.

The largest differences in the welfare effects of the simple target-price policy occur for relatively small target prices. The consumer benefits from the policy and its taxpayer costs are larger when quality responses are incorporated in the analysis. Relative to the estimate from the single-market model, the higher subsidy payments measured in the two-market model offset the higher gain to consumers, so that for a given target price, the net cost to consumers and taxpayers is larger. While the cost of the target-price policy is larger when quality responses are taken into account, so are the benefits to producers. This is not surprising, since producers receive benefits from target prices below the initial aggregate price, as discussed above. Contrary to the quota, where the DWL for a given quota quantity is actually smaller when allowing for quality adjustments, the DWL for a given target price is larger when quality responses are incorporated. Like the quota, where the DWL for a given transfer to producers was larger when allowing for quality adjustments, the DWL for a given transfer to producers, from a target-price policy, has a larger DWL when quality responses are incorporated.

5 Policy Implications

The previous sections make qualitative comparisons between the welfare effects of the quota and target-price policies with and without adjustments for quality responses. Quantitative comparisons may be made in a number of ways. One is to evaluate the magnitude of the errors in the welfare measures from incorrectly assuming constant quality. Another is to determine the values for policy instruments that would have equivalent effects in the two models. These evaluations are presented below.

5.1 Errors in Estimates of Welfare Effects

The percentage error in each welfare measure caused by using a model of a homogeneous good to approximate true policy effects is one measure of the importance of the quality responses to policies. Each percentage error is calculated as the absolute value of the difference between the change in welfare from the single- and two-market models, divided by the "correct" welfare change from the two-market model.

Figure 4 plots the percentage error in several welfare measures for the quota policy, as the quota quantity is varied. It is clear from figure 4, that even for very small market distortions (i.e., for quota quantities set close to the undistorted aggregate quantity of 1.0), the errors in the estimates of several welfare effects that are caused by assuming constant quality are quite large. The single-market model overstates the consumer loss by about 40 percent. The percentage error in producer benefits (including quota rent) is also approximately 40 percent for small reductions in total quantity. These percentage errors in CS and producer benefits decrease as the quota quantity is reduced. In contrast, the percentage error in DWL is nearly constant over all quota quantities, at approximately 40 percent. Finally, the percentage error in the DWL per dollar transferred to producers is quite small for small distortions in the market, and increases as the quota quantity is reduced.

Figure 5 shows the percentage errors in welfare changes for the target-price policy. For target prices set below the undistorted aggregate price but above the undistorted price in the low-quality market, the single-market model indicates no welfare change, and so the error in each welfare measure is 100 percent. The percentage errors decrease as the target price is increased above \$1.00. The percentage error in DWL reaches a minimum at about 50 percent. The error in DWL per dollar transferred to producers is also quite large (larger than it was for the quota policy), reaching a minimum of about 30 percent at the highest target price considered for these parameter values. The minimum errors in the changes in consumer and taxpayer welfare and producer benefits are over 20 percent. Thus, for both policies, the errors in the estimated welfare effects are quite large.

5.2 Policy Equivalence

Another way to evaluate the importance of quality effects is to determine the setting of a given policy instrument that would be necessary to achieve some policy goal (e.g., to attain a certain transfer to producers) assuming constant quality, and to compare it with the setting that would be required given variable quality. Taking the quota first, consider three different quota values: 0.65, 0.80, and 0.87. The transfer to producers (including quota rent) that would be expected using the single-market model of a homogeneous good and the actual transfer to producers from the two-market model that accounts for quality adjustments are listed in table 6, for each of these quota quantities.

Table 6: Estimated Producer Benefits from Quota Policies, as Measured in Single- and Two-Market Models

Quota Quantity	Expected Transfer to Producers From Single-Market Model	Actual Transfer to Producers From Two-Market Model
0.65	\$0.39	\$0.30
0.80	\$0.30	\$0.22
0.87	\$0.22	\$0.16

Using the single-market model, the estimated transfer to producers from a quota set at 0.80 would be \$0.30. However, because producers adjust the quality of their production in response to the quota, the 0.80 quota would only provide producer benefits of \$0.22. In order to transfer the \$0.30 intended, the quota would have to be set at 0.65. Similarly, the actual benefits provided by a quota of 0.80 are equal to what would be expected from a quota of 0.87, using the single-market model. This shows that quality responses substantially influence the quota quantity necessary to make a given transfer to producers. Further, as can be seen in the STCs in figure 1, the maximum producer benefit attainable by implementing a quota is substantially reduced (from \$0.40 to \$0.31) when quality responses are incorporated. This implies that unless it were combined with some other policy instrument, a quota would be inadequate for making transfers to producers greater than \$0.31.

Consider next simple target-price policies for target prices set at \$1.05, \$1.09, \$1.20, and \$1.30. The transfer to producers and the taxpayer cost from each model and for each target price are presented in table 7. Based on the homogeneous goods model, a target price

Table 7: Estimated Producer Benefits and Taxpayer Costs from Target-Price Policies, as Measured in Single- and Two-Market Models

Target Price	Expected Based on Single-Market Model		Actual Based on Two-Market Model	
	Transfer to Producers	Taxpayer Cost	Transfer to Producers	Taxpayer Cost
\$1.05	\$0.05	\$0.16	\$0.22	\$0.65
\$1.09	\$0.09	\$0.29	\$0.24	\$0.72
\$1.20	\$0.22	\$0.72	\$0.34	\$1.02
\$1.30	\$0.34	\$1.17	\$0.49	\$1.52

of \$1.20 would be expected to transfer \$0.22 to producers at a cost to taxpayers of \$0.72. The actual transfer and cost are substantially larger: a \$0.34 transfer to producers (what would have been expected from a target price of $1.30 in the aggregate market) at a cost to taxpayers of $1.02. In order to achieve an actual transfer of $0.22, the target price could be set much lower, at $1.05, reducing the taxpayer cost to $0.65. Similarly, if the goal of the policy were to provide the maximum benefit to producers without exceeding a budget of $0.72, the target price should be set at $1.09, rather than $1.20, for a transfer to producers of $0.24. As was true for the quota, incorporating quality responses into the analysis of target-price policies significantly alters the setting of the policy instrument that will meet a specific policy goal. For each policy, the single-market model implies policy settings larger than does the two-market model. A quota set too high will not achieve the desired transfer to producers, while a target price set too high will transfer more than intended to producers, at a substantially higher taxpayer cost.

As well as influencing the appropriate settings for policy instruments, given specific policy goals, quality responses also may change the choice of policy instrument for some policy goals. Figure 6 shows the STCs for a quota and a target-price policy from the single-market model (dashed lines), which intersect at a transfer to producers of $0.39. For transfers below $0.39, a quota policy is preferred, since it has a smaller DWL, and for larger transfers, the target-price policy is preferred. Figure 6 also includes the STCs from the two-market model (solid lines). The STCs from the two-market model intersect at a transfer to producers of $0.31, so that for smaller transfers, a quota is preferred, while for larger transfers, the target-price policy is preferred. Thus, for transfers between $0.31 and $0.39, a single-market model would indicate that a quota should be used, when a target-price policy actually incurs a smaller DWL.

6 Relationships Between Key Results and Specified Parameter Values

This section examines how the key results change as the parameters used to specify the models are varied. The elasticities, prices, and quantities used to initialize the model are varied one at a time, while holding all other parameters at their base values specified in section 4. The range of values used for each parameter is summarized in table 8.[3] For each new set of parameters, the effects of a quota and a simple target-price policy are evaluated, and the comparison of settings for policy instruments that have equivalent effects (as presented above) is repeated.

Table 8: Range of Values Considered for Parameters Used to Initialize Models

Parameter	Base Value	Minimum Absolute Value	Maximum Absolute Value
η	-0.50	0.05	2.50
σ	2.00	0.00	2.50
ϵ	1.00	0.05	2.50
τ	-0.50	0.05	2.50
P_H/P_L	3.00	1.00	3.00
Q_H/Q	0.50	0.25	0.75

The magnitude of the quality response to market interventions is the main determinant of the differences between the policy effects estimated using the single- and two-market models. As the magnitude of the quality response to a policy increases, so do the errors

[3] In varying the initial quality premium, P_H/P_L, between 1.0, which would indicate no quality premium, and 3.0, the base value, the initial quality-specific prices are varied so that the initial price in the aggregate market remains unchanged at one. Conversely, in varying the average quality at the undistorted equilibrium, Q_H/Q, the aggregate price and quantity are held equal to one. This is done by varying the initial prices, while keeping the price ratio constant at 3.0.

in the estimated welfare effects from using a single-market model. Correspondingly, as the magnitude of the quality response to a policy increases, so does the difference between the policy instrument settings implied by the two models (for a specified transfer to producers). Therefore, it is sufficient to examine how the quality responses to each policy vary with the specified parameters to determine the conditions under which the quantitative measures of the error from imposing constant quality increase.

Taking the quota policy first, for a given quota quantity, the quantity share of the high-quality good increases as the degree of substitutability between the two qualities increases (i.e., average quality increases more as σ and τ increase in magnitude). The quality response decreases as the scale effects in demand and supply are increased (i.e., as η and ϵ increase in magnitude). For these same parameter values, the percentage errors in DWL, CS, and producer benefits (shown in figure 4) also increase, and the quota settings from the single- and two-market models that would be estimated to achieve the same transfer to producers become increasingly disparate (i.e., the quota quantities reported in table 6 get farther apart). So, when the qualities of a commodity are quite substitutable either in supply or demand, or when the aggregate supply or demand is inelastic, the errors from ignoring quality responses to the quota policy will be larger.

For the target-price policy, the quality response to the target-price policy is driven by supply conditions. The most important parameter in determining the quality response is τ, the elasticity of transformation between low- and high-quality commodities. The decrease in average quality becomes more pronounced as the magnitude of τ is increased. As was true for the quota, when the quality response to the target-price policy increases, the percentage errors in the estimated welfare effects (shown in figure 5) become larger, and the target prices that would be estimated to achieve the same transfer to producers from the two models become more disparate (i.e., the target prices in table 7 get farther apart). So, when various qualities are easily transformed in the production process, the errors from using a single-market model to approximate the effects of a target-price policy will be larger.

Varying the average quality at the initial equilibrium does not influence the quality response to either policy much. In contrast, the influence of the quality premium at the initial undistorted equilibrium is quite pronouced. As the quality premium at the initial equilibrium increases, the magnitude of the quality response to each policy increases. If the magnitude of the quality premium reflects the true quality difference between the low- and high-quality varieties, then this result has a logical interpretation: the errors from ignoring quality responses increase as the extent of inherent quality variation in the commodity increases.

7 Concluding Remarks

The simple model presented here shows that imposing the assumption of product homogeneity in the analysis of a commodity that is actually heterogeneous may have important effects. If quality responses are ignored, and a single-market model is used to represent a hetergeneous commodity, substantial errors may be made in estimates of the costs and benefits to producers, consumers, and taxpayers. For the model and the parameter values used here, ignoring quality responses to policies results in errors in the estimated DWL from quota and target-price policies of over 40 percent. Interestingly, the direction as well as the size of the errors depend on the specifics of the policy. With the quota policy, true welfare effects are overestimated in the single-market model; with a target-price policy, the converse. In addition, the model of a homogeneous commodity and the two-market model that allows for quality responses imply different settings for policy instruments to meet a specific policy goal. For some policy goals, allowing for quality responses to policies even changes the preferred policy. The quantitative importance of these effects increases as the different qualities become more substitutable in demand and supply, as overall demand and supply elasticities decrease in magnitude, and as the quality premium increases.

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Figure 1. Surplus Transformation Curves for a Quota

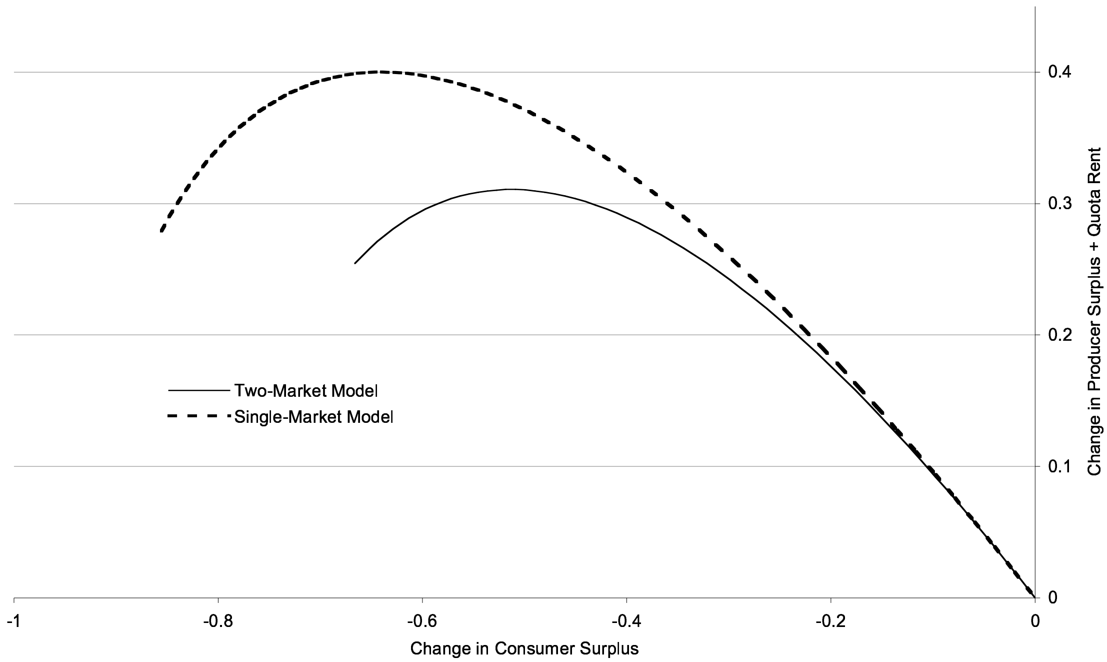

Figure 2. Quota Rent from a Quota

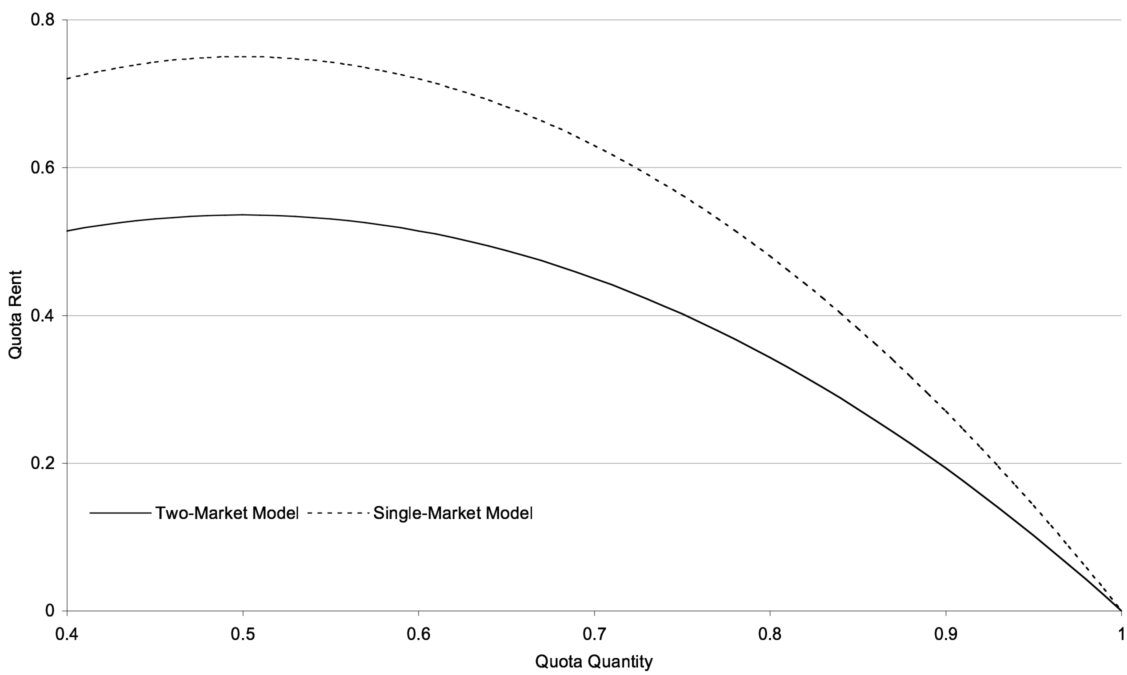

Figure 3. Surplus Transformation Curves for a Simple Target-Price Policy

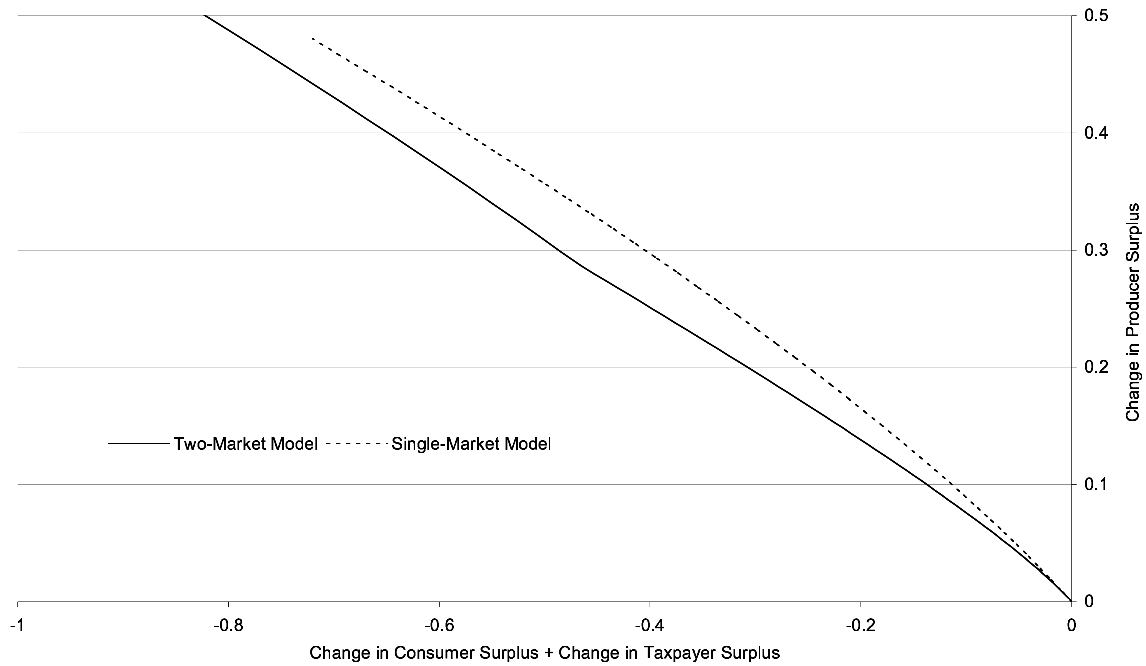

Figure 4. Percentage Errors in Selected Welfare Measures for a Quota Policy

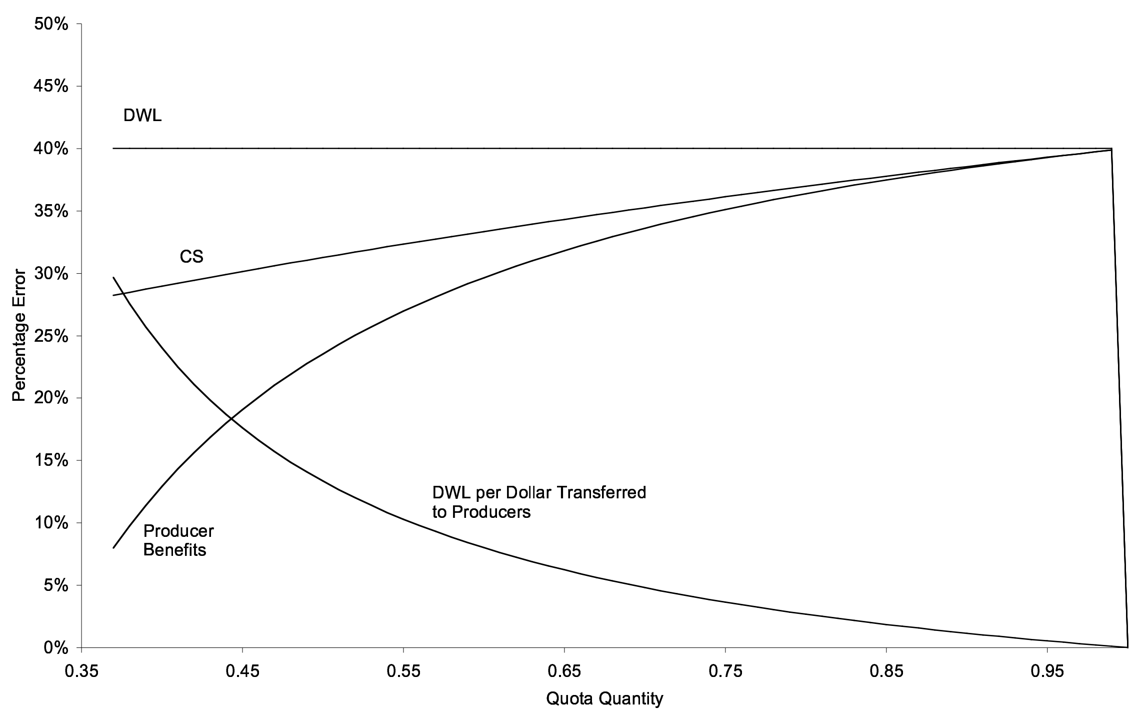

Figure 5. Percentage Errors in Selected Welfare Measures for a Target-Price Policy

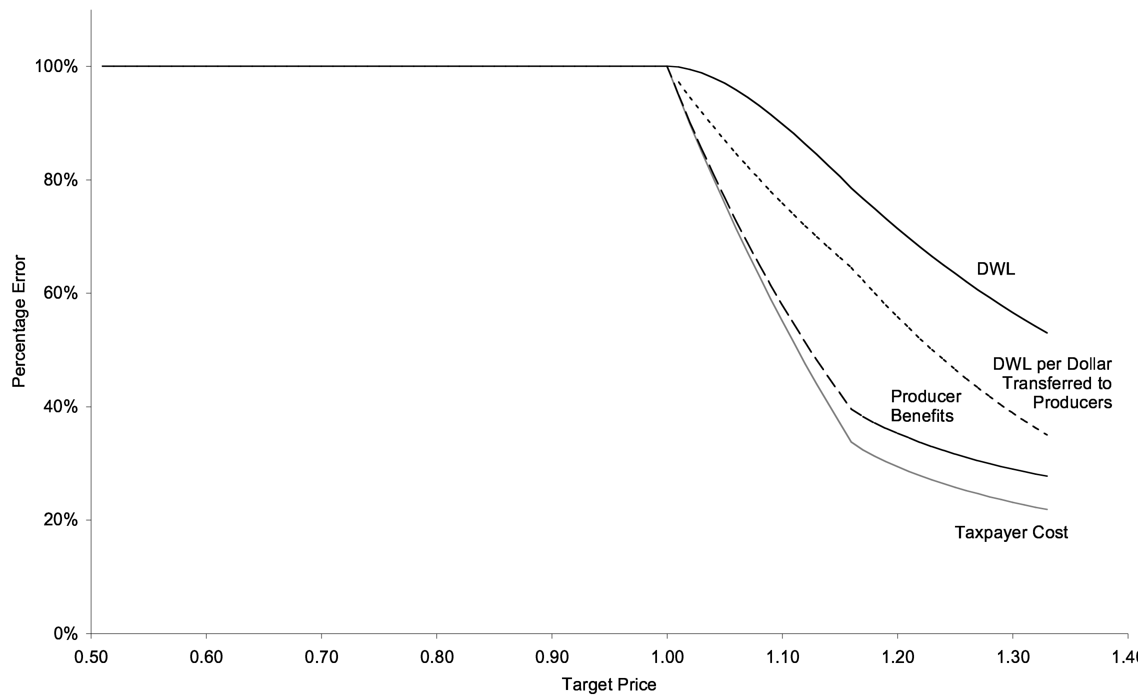

Figure 6. Surplus Transformation Curves for Quota and Target-Price Policies from the Single-Market and Two-Market Models