DISCUSSION PAPERS IN ECONOMICS

Working Paper No. 02-18

Inequality and Pharmaceutical Drug Prices: A Theoretical Exercise

Eina Vivian Wong
Department of Economics, University of Colorado at Boulder
Boulder, Colorado

October 2002

Center for Economic Analysis
Department of Economics

University of Colorado at Boulder
Boulder, Colorado 80309

Inequality and Pharmaceutical Drug Prices:

A Theoretical Exercise

Eina Vivian Wong

University of Colorado

October 17, 2002

Abstract:

Several studies report that in both developed and developing countries, the relatively poor individuals go without medical care, including pharmaceuticals. This situation is associated with both low income and inequality in the distribution of income. Additionally, data show that pharmaceutical prices in developing countries are sometimes higher than those in developed countries for identical products. In this paper, I explore the relationship between per capita income, inequality, and prices. Specifically, I develop a model of demand that shows the equilibrium price of a pharmaceutical drug produced by a monopolist will rise with (1) per capita income and (2) income inequality. In the context of multiple countries, the former result corroborates empirical findings on the statistically significant effect of per capita income on drug prices. The latter result has not been empirically tested. The results from this paper are, however, conducive to nonlinear regression techniques so that income inequality may be tested as a source of variation of drug prices across countries.

I. Introduction

Several studies report that in both developed and developing countries, the relatively poor individuals go without medical care, including pharmaceuticals.[1] This situation is associated with both low income and inequality in the distribution of income. Additionally, data show that pharmaceutical prices in developing countries are sometimes higher than those in developed countries for identical products.[2] In this paper, I explore the relationship between per capita income, inequality, and pharmaceutical prices. Specifically, I develop a model of demand that shows the equilibrium price of a pharmaceutical drug produced by a monopolist will rise with (1) income inequality and (2) per capita income.

The decision to purchase a pharmaceutical may be explained by a model of identical, non-homothetic preferences. Suppose, for example, that an individual may first consider how much of a necessary good, such as food, to purchase. If no income is left after buying food, then he does not consume the drug. In other words, there exists a minimum income requirement to purchase a pharmaceutical. Individuals whose incomes are greater than the minimum income requirement will purchase the drug. Thus, the budget share of each commodity is dependent on the level of individual income and not on aggregate income.

Most conventional models of preferences use homogeneous functions for analytical tractability. But these models naturally restrict demand to be unit elastic with respect to income. In addition, it can be shown for all standard functions, such as constant elasticity of substitution preferences, that the price elasticity of demand for any good depends only on relative prices and not on income. Assuming a monopoly supplier of a good whose markup is based on the price

[1] Feachem et al (1992), Mapelli (1993), Castro-Leal et al (2000), Makinen et al (2000).
[2] Data are from IMS Health.

elasticity of demand, these models thus do not produce the result that the markup and hence equilibrium price will depend in any way on per capita income. Put another way, there is no distinction for equilibrium pricing between having more consumers and having richer consumers.

There are, of course, many alternatives for modeling non-homothetic preferences. In this paper, I develop a variation on the well-known Stone-Geary utility function which not only generates an income elasticity of demand for pharmaceuticals that is greater than one, but the price elasticity of demand for this good falls with increases in per capita income. Thus the monopoly markup and equilibrium price will rise as per capita income increases.

I then turn to the role of income inequality and show how changes in the distribution of income affect the market price elasticity of demand and therefore monopoly markup and equilibrium price. Using the preferences just described, I show that as inequality rises, market demand becomes less price elastic even for mean-preserving spreads in the distribution. Such a rise in the equilibrium price then also affects an individual's ability to meet the minimum income requirement to purchase the drug. An exogenous increase in dispersion makes the poor individuals poorer. For individuals who previously met the minimum income requirement by a margin, an increase in dispersion constrains their choice sets. That is, some of those who previously could afford to buy the pharmaceutical will not be able to afford it with increasing income inequality. Aggregate demand for the drug decreases. These results do not occur in a model with homothetic preferences, in which price elasticities of demand do not fluctuate with income level and the distribution of income is ignored.

I model three types of income dispersion to show the effect on equilibrium price. In the first model, increasing dispersion is a first-order stochastically dominant change. The other two models show increasing dispersion as mean preserving spreads. I show that, when aggregating demand, increasing dispersion leads to a higher equilibrium price for the pharmaceutical. The equilibrium (aggregate) demand for the pharmaceutical decreases as a result of the increase in price and the increase in the minimum income requirement. These results are independent of the type of dispersion. In addition, the equilibrium price is an increasing function of per capita income. That the price of a pharmaceutical is a function of both inequality and per capita income reflects what may be occurring among countries with varying drug prices, per capita income, and inequality measures.

Demand in this framework differs from the linear expenditure system derived from the Stone-Geary utility function in which demand for other commodities, such as food, has a "minimum consumption requirement." The utility function associated with that system also requires a minimum income requirement in order for the individual to consume the luxury good. Utility is, however, undefined for income levels less than this requirement. In addition, the price elasticity of demand does not vary with income level. My alternative to the Stone-Geary utility function and the linear expenditure system overcomes both of these problems.

II. Preferences:

Utility for individual i is represented by:

$$U_i = (X_i + C)^{\alpha} Y_i^{\beta}, \qquad i = 1,\ldots,N \qquad \alpha, \beta > 0 \tag{1}$$

where X_i is individual i's demand for pharmaceuticals, Y_i is his demand for a composite good (e.g., basic necessities such as food and shelter). C is a shift parameter and is positive, which makes preferences non-homothetic. It is identical for all individuals. α and β are budget shares, identical for all individuals. Thus, preferences are identical across individuals.

(1) captures quasi-homothetic preferences. The wealth expansion path does not start at the origin. When it does begin, however, the path is linear. That is, consumption of *X* and *Y* are constant with respect to increases in income. Without the shift parameter *C*, (1) is the usual Cobb-Douglas function with homothetic preferences and unit elastic demands with respect to income and price.

The budget constraint for individual *i* is:

$$w_i = p_x X_i + p_y Y_i \tag{2}$$

where p_x and p_y are prices of *X* and *Y*, respectively. w_i is individual *i*'s income level.

Indifference Curves

The marginal rate of substitution between X and Y is:

$$MRS_{xy} \equiv -\frac{\frac{\partial U_x}{\partial X_i}}{\frac{\partial U_y}{\partial Y_i}} = -\frac{\alpha(X_i + C)^{\alpha - 1} Y_i^{\beta}}{\beta(X_i + C)^{\alpha} Y_i^{\beta - 1}} = -\frac{\alpha}{\beta}\frac{Y_i}{X_i + C} \tag{3}$$

Note that when *C* is zero, the marginal rate of substitution is identical to that of the traditional Cobb-Douglas problem:

$$MRS_{xy}^{C-D} \equiv -\frac{\dfrac{\partial U_x}{\partial X_i}}{\dfrac{\partial U_y}{\partial Y_i}} = -\frac{\alpha}{\beta}\frac{Y_i}{X_i} \tag{4}$$

Thus, in our model, the indifference curves are everywhere flatter relative to those of the Cobb-Douglas model. See Figure 1. In maximizing utility, an individual must consume the amounts of X and Y where the indifference curve is tangent to the budget line. This point occurs when income is greater than the minimum income requirement $w_i > w^o$. See Figure 2. The income expansion path is shifted upwards (along Y-axis).

To solve the utility maximization problem, I solve the first order conditions from the Lagrangian:

$$\begin{aligned}
L_i &= (X_i + C)^{\alpha} Y_i^{\beta} + \lambda_i (w_i - p_x X_i - p_y Y_i) \\
\frac{\partial L_i}{\partial X_i} &= \alpha (X_i + C)^{\alpha - 1} Y_i^{\beta} - \lambda_i p_x \le 0, \quad X_i \ge 0 \\
\frac{\partial L_i}{\partial Y_i} &= \beta (X_i + C)^{\alpha} Y_i^{\beta - 1} - \lambda_i p_y \le 0, \quad Y_i \ge 0 \\
\frac{\partial L_i}{\partial \lambda_i} &= w_i - p_x X_i - p_y Y_i = 0
\end{aligned} \tag{5}$$

(5) yields the following demand specification for the pharmaceutical:

$$X_i = \begin{cases} \dfrac{\alpha}{\alpha + \beta}\left(\dfrac{w_i - w^o}{p_x}\right), & w_i > w^o \\ 0, & w_i \leq w^o \end{cases} \tag{6}$$

where $w^o = \frac{\beta C}{\alpha} p_x$. Demand for other goods is:

$$Y_i = \begin{cases} \dfrac{1}{\alpha + \beta}\left(\dfrac{\beta w_i + \alpha w^o}{p_y}\right), & w_i > w^o \\ \dfrac{w_i}{p_y}, & w_i \leq w^o \end{cases} \tag{7}$$

(6) tells us that demand for pharmaceuticals is positive only if an individual's income is greater than some threshold level, w^o. w^o is a function of the ratio of budget shares, the price of the pharmaceutical, and the shift parameter. Since these are identical for all consumers, the threshold level is the same for everyone. The Engel curve is illustrated in Figure 3. This shows the demand for the pharmaceutical as a function of income, holding price constant. It is kinked at the threshold level.

The demand for Y also changes depending on the individual's income. When $w_i \leq w^o$, the individual allocates all of his income to consumption of Y.

Consumption of X and Y

The ratio $\frac{X_i}{Y_i}$ illustrates the relationship between the present model and the usual Cobb-Douglas utility specification. The ratio is:

$$\frac{X_i}{Y_i} = \frac{\alpha(w_i - w^o)}{(\alpha + \beta)p_x} \frac{(\alpha + \beta)p_y}{\beta w_i + \alpha w^o} = \frac{p_y}{p_x} \frac{\alpha w_i - \alpha w^o}{\beta w_i + \alpha w^o} \tag{8}$$

As an individual's income increases, this consumption ratio also increases:

$$\begin{aligned}
\frac{\partial \frac{X_i}{Y_i}}{\partial w_i} &= \frac{p_y}{p_x} \left[\frac{\alpha(\beta w_i + \alpha w^o) - \beta(\alpha w_i - \alpha w^o)}{(\beta w_i + \alpha w^o)^2}\right] \\
&= \frac{p_y}{p_x} \left[\frac{\alpha\beta w_i + \alpha^2 w^o - \alpha\beta w_i + \alpha\beta w^o)}{(\beta w_i + \alpha w^o)^2}\right] \\
&= \frac{p_y}{p_x} \frac{\alpha(\alpha + \beta) w^o}{(\beta w_i + \alpha w^o)^2} > 0 \\
\frac{\partial^2 \frac{X_i}{Y_i}}{\partial w_i^2} &= -2 \frac{p_y}{p_x} \frac{\alpha\beta(\alpha + \beta) w^o}{(\beta w_i + \alpha w^o)^3} < 0
\end{aligned} \tag{9}$$

The first partial derivative in (9) says that with increasing income, an individual's consumption of *X* rises faster than the consumption of *Y*. In the limit, the ratio approaches the traditional Cobb-Douglas consumption ratio:

$$\begin{aligned}
\lim_{w_i \to w^o} \frac{X_i}{Y_i} &= 0 \\
\lim_{w_i \to \infty} \frac{X_i}{Y_i} &= \frac{\alpha}{\beta} \frac{p_y}{p_x}
\end{aligned} \tag{10}$$

This relationship is illustrated in Figure 4. The reason the consumption ratio approaches the Cobb-Douglas ratio is that as individual income rises, the effect of the minimum income requirement diminishes. If everyone's income increases systematically, eventually everyone's income will surpass the minimum requirement. Recall, the Cobb-Douglas specification does not require any income requirement for consumption of both goods. In this context, the Cobb-Douglas function may be considered the asymptotic utility specification with respect to income.

<u>Properties of Demand</u>

Income Elasticity of Demand (for X > 0)

The usual Cobb-Douglas specification results in unit income elasticities. With the shift parameter *C*, the income elasticities of demand are not unity.

The income elasticity of demand for pharmaceuticals is:

$$\frac{\partial X_i}{\partial w_i} = \frac{\alpha}{\alpha + \beta} \frac{1}{p_x}$$
$$\eta_x \equiv \frac{\partial X_i}{\partial w_i} \frac{w_i}{X_i} = \frac{\alpha}{\alpha + \beta} \frac{1}{p_x} w_i \frac{(\alpha + \beta) p_x}{\alpha (w_i - w^o)} = \frac{w_i}{w_i - w^o} > 1 \tag{11}$$

A pharmaceutical is a luxury good in this model. The effect of increasing income on the income elasticity is negative:

$$\frac{\partial \eta_x}{\partial w_i} = \frac{w_i - w^o - w_i}{w_i - w^o} = -\frac{w^o}{w_i - w^o} < 0$$
$$\frac{\partial^2 \eta_x}{\partial w_i^2} = \frac{w^o}{(w_i - w^o)^2} > 0 \tag{12}$$

As income rises, the pharmaceutical becomes less of a luxury at an increasing rate, but will always remain a luxury good. This is illustrated in Figure 5. The income elasticity approaches one as income tends to infinity. That is, the pharmaceutical is considered a luxury by all individuals, regardless of income level.

Y is a necessary good. The income elasticity of Y is:

$$\frac{\partial Y_i}{\partial w_i} = \frac{\beta}{\alpha + \beta}\frac{1}{p_y}$$

$$\eta_y \equiv \frac{\partial Y_i}{\partial w_i}\frac{w_i}{Y_i} = \frac{\beta}{\alpha + \beta}\frac{1}{p_y} w_i \frac{(\alpha + \beta)p_y}{\beta w_i + \alpha w^o} = \frac{\beta w_i}{\beta w_i + \alpha w^o} < 1 \tag{13}$$

The effect of increasing income on the income elasticity of Y is positive:

$$\frac{\partial \eta_y}{\partial w_i} = \frac{\beta(\beta w_i + \alpha w^o) - \beta^2 w_i}{(\beta w_i + \alpha w^o)^2} = \frac{\alpha\beta w^o}{(\beta w_i + \alpha w^o)^2} > 0$$

$$\frac{\partial^2 \eta_y}{\partial w_i^2} = -\frac{2\alpha\beta^2 w^o}{(\beta w_i + \alpha w^o)^3} < 0 \tag{14}$$

As income rises, Y becomes less of a necessary good at a decreasing rate, but will always remain a necessary good. Figure 5 shows that the income elasticity of Y with respect to income is a positive, concave function, with an upper limit of one. That is, Y is considered a necessary good by all individuals regardless of income level.

Price Elasticity of Demand (for $X > 0$)

In the usual Cobb-Douglas specification, price elasticities of demand are unity. Here, with non-homothetic preferences, demand for the pharmaceutical is elastic. It is this feature of demand that drives the results.

Individual demand for pharmaceuticals:

$$
\begin{aligned}
X_i &= \frac{\alpha}{\alpha+\beta}\frac{w_i - w^o}{p_x} = \frac{1}{\alpha+\beta}\left(\frac{\alpha w_i - \alpha w^o}{p_x}\right) \\
&= \frac{1}{\alpha+\beta}\left(\frac{\alpha w_i}{p_x} - \beta C\right)
\end{aligned}
\tag{15}
$$

The price elasticity of demand is:

$$
\begin{aligned}
\frac{\partial X_i}{\partial p_x} &= -\frac{\alpha}{\alpha+\beta}\frac{w_i}{p_x^2} \\
\epsilon_x \equiv \frac{\partial X_i}{\partial p_x}\frac{p_x}{X_i} &= -\frac{\alpha}{\alpha+\beta}\frac{w_i}{p_x^2}\frac{(\alpha+\beta)p_x}{\alpha w_i - \beta p_x C} = -\frac{\alpha w_i}{\alpha w_i - \beta p_x C} \\
&= -\frac{\alpha w_i}{\alpha w_i - \alpha w^o} = -\frac{w_i}{w_i - w^o} \\
|\epsilon_x| &= \frac{w_i}{w_i - w^o} > 1 \\
\lim_{w_i \to w^o} |\epsilon_x| &= \frac{w^{o^+}}{w^{o^+} - w^o} = +\infty \\
\lim_{w_i \to \infty} |\epsilon_x| &= \frac{\infty}{\infty - w^o} = 1
\end{aligned}
\tag{16}
$$

The limits in (16) tell us that demand will remain elastic for every income level. As an individual's income rises, his demand will be relatively less elastic at an increasing rate:

$$\frac{\partial|\epsilon_x|}{\partial w_i} = \frac{w_i - w^o - w_i}{(w_i - w^o)^2} = -\frac{w_i}{(w_i - w^o)^2} < 0$$

$$\frac{\partial^2|\epsilon_x|}{\partial w_i^2} = \frac{2w^o}{(w_i - w^o)^3} > 0 \tag{17}$$

Figure 6 illustrates this relationship. As income tends to infinity, it approaches one (the Cobb-Douglas price elasticity). That is, demand for the pharmaceutical is elastic for all individuals regardless of income level. As income rises, the price elasticity of demand in absolute value is decreases. The demand of high-income individuals is price inelastic relative to the demand of low-income individuals.

Demand for *Y* is:

$$Y_i = \frac{1}{\alpha + \beta}\frac{(\beta w_i + \alpha w^o)}{p_y}$$

$$\frac{\partial Y_i}{\partial p_y} = -\frac{1}{\alpha + \beta}\frac{(\beta w_i + \alpha w^o)}{p_y^2} \tag{18}$$

The price elasticity of demand for other goods *Y* is:

$$\epsilon_y \equiv \frac{\partial Y_i}{\partial p_y}\frac{p_y}{Y_i} = -\frac{1}{\alpha + \beta}\left(\frac{\beta w_i + \alpha w^o}{p_y^2}\right)p_y\frac{(\alpha + \beta)p_y}{\beta w_i + \alpha w^o} = -1 \tag{19}$$

Demand for *Y* is unit elastic; that is, the elasticity does not vary with income level. This is intuitive, given that *Y* is a necessary good.

III. Monopoly Pricing

The utility function (1) captures quasi-homothetic preferences. In other words, when all consumers face the same price, aggregation across demand functions is possible, allowing the use of community indifference curves. The equilibrium price becomes a function of per capita income. To demonstrate, I first ignore the distribution of income, and sum individual demands (6) across all individuals. Market demand is:

$$\begin{aligned} X(p_x, W) &\equiv \sum_i^N X_i(p_x, w_i) = \frac{\alpha}{\alpha+\beta} \sum_i^N \left(\frac{w_i}{p_x} - \frac{\beta C}{\alpha}\right) \\ &= \frac{\alpha}{\alpha+\beta}\left(\frac{W}{p_x} - \frac{N\beta C}{\alpha}\right) \end{aligned} \tag{20}$$

W is aggregate income and N is the population size. In dividing through by N, the expression becomes per capita demand as a function of mean income.

$$\begin{aligned} \overline{X} \equiv \frac{X}{n} &= \frac{\alpha}{\alpha+\beta}\left(\frac{W}{np_x} - \frac{\beta C}{\alpha}\right) \\ &= \frac{\alpha}{\alpha+\beta}\left(\frac{\overline{w}}{p_x} - \frac{\beta C}{\alpha}\right) \\ &= \frac{\alpha}{\alpha+\beta}\left(\frac{\overline{w} - w^o}{p_x}\right) \end{aligned} \tag{21}$$

where $\overline{X}$ and $\overline{w}$ are per capita demand and per capita income, respectively.

The monopolist's profit maximizing problem may be solved using per capita demand (21):

$$\pi = (p_x - m)X(p_x,\overline{w}) - FC$$
$$= \frac{\alpha}{\alpha + \beta}\frac{(p_x - m)}{p_x}(\overline{w} - w^o) - FC \qquad \textbf{(22)}$$

where m is the constant marginal cost and FC is the fixed cost. Noting that w^o is a function of p_x, maximizing (22) yields:

$$\frac{d\pi}{dp_x} = \frac{\partial\pi}{\partial p_x} + \frac{\partial\pi}{\partial X}\frac{dX}{dp_x} + \frac{\partial\pi}{\partial X}\frac{\partial X}{\partial w^o}\frac{dw^o}{dp_x}$$
$$= \frac{\alpha}{\alpha + \beta}\left[\frac{m}{p_x^2}(\overline{w} - w^o) + (-)\frac{dw^o}{dp_x}\left(\frac{p_x - m}{p_x}\right)\right]$$
$$= \frac{\alpha}{\alpha + \beta}\left[\frac{m}{p_x^2}(\overline{w} - w^o) - \frac{w^o}{p_x}\left(\frac{p_x - m}{p_x}\right)\right] \qquad \textbf{(23)}$$
$$= \frac{\alpha}{\alpha + \beta}\frac{1}{p_x^2}[m\overline{w} - mw^o - p_x w^o + mw^o]$$
$$= \frac{\alpha}{\alpha + \beta}\frac{1}{p_x^2}[m\overline{w} - p_x w^o]$$

Setting (23) equal to zero and solving for the equilibrium price, we have:

$$p_x^{(} = \left(\frac{\alpha m\overline{w}}{\beta C}\right)^{\frac{1}{2}} \qquad \textbf{(24)}$$

(24) shows the equilibrium price of the pharmaceutical as a function of per capita income. Thus, in the context of multiple countries, the equilibrium (autarky) price of the pharmaceutical will differ, depending on per capita income. Because the minimum income requirement is a

function of price, countries with different per capita incomes will also have different minimum requirements. Demand thus fluctuates with per capita income. These results do not hold when using total income. That is, there is no difference between having more consumers and having richer consumers.

IV. Income Distributions and Increasing Inequality

The role of income inequality is to show that the price elasticity of demand--at both the individual and aggregate levels--drives the results. Rising inequality lowers the price elasticity of market demand (in absolute value) because the rich are getting richer. As a result, the equilibrium price rises.

With increasing inequality, fewer people are able to meet the minimum requirement. This occurs for two reasons. First, an increase in inequality has the direct effect of lowering income levels for some people. Specifically, for those who met the minimum income requirement marginally, a decrease in income to less than the requirement will mean that they no longer afford the pharmaceutical. Secondly, an increase in inequality increases the equilibrium price of the pharmaceutical, which also increases the minimum income requirement. This indirect effect exacerbates the problem just described. With fewer people able to meet the minimum requirement, aggregate demand for the pharmaceutical decreases.

When including the distribution of income in the analysis, the market or aggregate demand function does not take the same form as individual demand, as in the previous section. Rather, aggregate demand is the sum of individual demands, taking into consideration the probability density of income. That is, if there are more poor people than rich people, aggregate demand would be less relative to an economy with more rich people than poor people. In a model with homothetic preferences, the distribution of income has no effect on aggregate demand. Nevertheless, with quasi-homothetic preferences, aggregate demand may still be expressed as a function of per capita income. Thus, the equilibrium price is a function of per capita income.

The rest of the paper shows how income inequality and per capita income affect the equilibrium price and demand of the pharmaceutical. As a measure of inequality, I use the dispersion of income distribution, to be defined below.

The analysis is divided into three sections, each detailing a specific type of income dispersion. The first model uses a uniform income distribution. Dispersion is increased by extending only the upper bound of the income support. In the second model, dispersion is increased by extending the entire support (i.e., both lower and upper bounds) so as to create a mean preserving spread. The final model benchmarks a step distribution (approximating a normal distribution). Dispersion is increased by flattening the middle of the distribution and raising the ends (to a uniform distribution, for example), thereby preserving the mean and income support. The differences between these models are summarized in the Appendix table.

A. Model 1: Uniform Income Distribution and First Order Stochastic Dominance

Income distribution:

Suppose income is distributed uniformly among members of the economy, taking values between w^l and w^u. There is a continuum of individuals, with no two individuals having the same income level. This implies that each individual will demand a unique amount of *X*. Individuals are ranked by income level from lowest to highest. The benchmark income distribution is:

$$f(w) = \frac{1}{w^u - w^l}, \quad 0 \leq w^l \leq w \leq w^u \tag{25}$$

Aggregate demand is the sum of individual demands, given a price level p_x:

$$\begin{aligned} X(p,w) &= \int_{w^l}^{w^u} X_i(w)\, dF(w) \\ &= \int_{w^l}^{w^o} X_i(w)\, dF(w) + \int_{w^o}^{w^u} \frac{1}{w^u - w^l} \frac{\alpha}{\alpha + \beta} \frac{w - w^o}{p_x} dw \\ &= 0 + \frac{1}{(w^u - w^l)p_x} \frac{\alpha}{\alpha + \beta} \left(\frac{w^2}{2} - w w^o\right) \Big|_{w^o}^{w^u} \\ &= \frac{\alpha}{\alpha + \beta} \frac{(w^u - w^o)^2}{2(w^u - w^l)p_x}, \qquad w^l < w^o \end{aligned} \tag{26}$$

where *F(w)* is the cumulative income distribution of *f(w)*.

Profit Maximization:

There is a monopolist that produces *X* with increasing returns to scale. Profits are:

$$\begin{aligned} \pi &= (p_x - m)X(p,w) - FC \\ &= \frac{\alpha}{\alpha + \beta} \frac{1}{2(w^u - w^l)} \left(\frac{p_x - m}{p_x}\right)(w^u - w^o)^2 - FC \end{aligned} \tag{27}$$

where m is a constant marginal cost and FC is a fixed cost. Maximizing (27) with respect to p_x yields: (and noting that $\frac{dw^o}{dp_x} = \frac{\beta C}{\alpha} = \frac{w^o}{p_x}$)

$$\frac{d\pi}{dp_x} = \frac{\alpha}{\alpha + \beta}\frac{1}{2(w^u - w^l)}[\frac{m}{p_x^2}(w^u - w^o)^2 + 2(w^u - w^o)(-\frac{dw^o}{dp_x})(\frac{p_x - m}{p_x})]$$

$$= \frac{\alpha}{\alpha + \beta}\frac{1}{2(w^u - w^l)p_x^2}(w^u - w^o)[m(w^u - w^o) - 2w^o(p_x - m)] \quad \textbf{(28)}$$

$$= \frac{\alpha}{\alpha + \beta}\frac{1}{2(w^u - w^l)p_x^2}(w^u - w^o)[m(w^u + w^o) - 2w^o p_x]$$

Setting (28) equal to zero, I substitute $w^o = \frac{\beta C}{\alpha}p_x$ and solve for equilibrium prices:

$$p_x{}^o = \frac{\alpha w^u}{\beta C} \quad \textbf{(29)}$$

$$p_x^{(} = \frac{m}{4} + \frac{1}{2}(\frac{m^2}{4} + \frac{2m\alpha w^u}{\beta C})^{\frac{1}{2}} \quad \textbf{(30)}$$

(29) is a choke price, or the price at which demand is zero. Thus, it is not useful in the analysis of dispersion. (30) is the price of interest. Note that it is higher than the monopoly price when the distribution of income is ignored (24). This foreshadows the result that inequality resulting from aggregating demand positively affects price. In addition, it is straightforward to show that (30) is a function of the per capita income of individuals whose income levels are greater than the minimum requirement.[3] That is, the equilibrium price also increases with per capita income

[3]The mean income of individuals increases with the upper limit of income, w^u.

when incorporating the distribution of income.

Dispersion:

Now consider an increase in the upper support of the income range by an amount δ. An increase in the maximum income level to $(w^u + \delta)$ increases the mean and dispersion. In the context of multiple countries, this situation compares a high-per capita income, high-inequality country to one with lower per capita income and inequality. For example, the United States has higher per capita income and Gini coefficient relative to the Czech Republic. The United States also has higher average pharmaceutical prices.[4]

The change in income distribution is shown in Figure 7. The new distribution is:

$$g(w) = \frac{1}{w^u + \delta - w^l}, \qquad w^l \leq w \leq w^u + \delta \tag{31}$$

Total income is the sum of expected incomes: $W = N\mu$, where N is the number of individuals, and μ is the mean income. Thus, total income increases with mean income. The cumulative distribution *G(w)* first order stochastically dominates *F(w)* because:

$$\int_w F(w)\,dw > \int_w G(w)\,dw \qquad \forall w \tag{32}$$

In other words, the distribution *G(w)* is preferred over *F(w)*. See Figure 8. (32) says that the Lorenz curve associated with *G(w)* is everywhere higher than the Lorenz curve associated with

[4]IMS Health.

F(w).[5] That is, we have Lorenz dominance.

Aggregate demand under the new distribution is:

$$X(p_x, w, \delta) = \int_{w^l}^{w^u+\delta} X_i(w)\, dG(w)$$

$$= \int_{w^l}^{w^o} X_i(w)\, dG(w) + \int_{w^o}^{w^u+\delta} \frac{1}{w^u + \delta - w^l} \frac{\alpha}{\alpha + \beta} \left(\frac{w - w^o}{p_x}\right) dw$$

$$= 0 + \frac{1}{(w^u + \delta - w^l)p_x} \frac{\alpha}{\alpha + \beta} \left(\frac{w^2}{2} - w w^o\right)\Big|_{w^o}^{w^u+\delta} \tag{33}$$

$$= \frac{1}{(w^u + \delta - w^l)p_x} \frac{\alpha}{\alpha + \beta} \left[\frac{(w^u + \delta)^2}{2} - (w^u + \delta)w^o - \frac{w^{o^2}}{2} + w^{o^2}\right]$$

$$= \frac{\alpha}{\alpha + \beta} \frac{(w^u + \delta - w^o)^2}{2(w^u + \delta - w^l)p_x}$$

Note that when $\delta = 0$, (33) is identical to (26).

Maximizing profits with this new expression for aggregate demand:

$$\pi = (p_x - m) X(p_x, w, \delta) - FC$$

$$= \frac{\alpha}{\alpha + \beta} \frac{1}{2(w^u + \delta - w^l)} \left(\frac{p_x - m}{p_x}\right) (w^u + \delta - w^o)^2 - FC \tag{34}$$

(and noting that $\frac{dw^o}{dp_x} = \frac{\beta C}{\alpha} = \frac{w^o}{p_x}$):

[5] Atkinson (1970).

$$\frac{d\pi}{dp_x} = \frac{\alpha}{\alpha+\beta}\frac{1}{2(w^u+\delta-w^l)}\left[\frac{m}{p_x^2}(w^u+\delta-w^o)^2 + 2(w^u+\delta-w^o)(-\frac{dw^o}{dp_x})(\frac{p_x-m}{p_x})\right]$$

$$= \frac{\alpha}{\alpha+\beta}\frac{1}{2(w^u+\delta-w^l)p_x^2}(w^u+\delta-w^o)[m(w^u+\delta-w^o) - 2w^o(p_x-m)] \qquad \textbf{(35)}$$

$$= \frac{\alpha}{\alpha+\beta}\frac{1}{2(w^u+\delta-w^l)p_x^2}(w^u+\delta-w^o)[m(w^u+\delta) + mw^o - 2w^o p_x]$$

Setting (35) equal to zero and substituting $w^o = \frac{\beta C}{\alpha}p_x$, and solving for equilibrium prices, I get:

$$p_x{}^o(\delta) = \frac{\alpha(w^u+\delta)}{\beta C} \qquad \textbf{(36)}$$

$$p_x^{(}(\delta) = \frac{m}{4} + \frac{1}{2}(\frac{m^2}{4} + \frac{2m\alpha(w^u+\delta)}{\beta C})^{\frac{1}{2}} \qquad \textbf{(37)}$$

(36) is a choke price. I use (37) to perform comparative statics. This price is higher than the equilibrium price (30) without dispersion. Thus, rising inequality and per capita income increases the equilibrium price of the pharmaceutical.

I am particularly interested in how increasing dispersion affects the equilibrium price of the pharmaceutical:

$$\frac{d\breve{p}_x}{d\delta} = \frac{m\alpha}{2\beta C}\left[\frac{m^2}{4} + \frac{2m\alpha(w^u + \delta)}{\beta C}\right]^{-\frac{1}{2}} > 0$$

$$\frac{d^2\breve{p}_x}{d\delta^2} = -\frac{m\alpha}{4\beta C}\left[\frac{m^2}{4} + \frac{2m\alpha(w^u + \delta)}{\beta C}\right]^{-\frac{3}{2}}\frac{2m\alpha}{\beta C} \tag{38}$$

$$= \frac{1}{2}\left(\frac{m\alpha}{\beta C}\right)\left[\frac{m^2}{4} + \frac{2m\alpha(w^u + \delta)}{\beta C}\right]^{-\frac{3}{2}} < 0$$

An increase in dispersion increases the equilibrium price of the drug at a decreasing rate. I.e., the relationship between equilibrium price and dispersion is positive and concave. See Figure 9. This is the result of the decrease in price elasticity of market demand due to dispersion. In general terms, this effect is:

$$|\epsilon_x| = \epsilon[\delta, w^o(\breve{p}_x(\delta))]$$

$$\underset{}{\frac{d|\epsilon_x|}{d\delta}} = \underset{(-)}{\frac{\partial|\epsilon_x|}{\partial\delta}} + \underset{(-)}{\frac{\partial|\epsilon_x|}{\partial w^o}}\,\underset{(+)}{\frac{\partial w^o}{\partial\breve{p}_x}}\,\underset{(+)}{\frac{d\breve{p}_x}{d\delta}} \tag{39}$$

(39) is negative. The first term to the right of the equal sign is the effect of making the rich people richer. The second term results from excluding the portion of the population that cannot meet the minimum income requirement.

Substitute (37) into (33) and taking the derivative with respect to δ gives the effect of dispersion on aggregate demand. In general form, the expression is:

$$X^* = X[\delta, p_x^*(\delta), w^o(p_x^*(\delta))]$$

$$\frac{dX^*}{d\delta} = \underset{(+)}{\frac{\partial X^*}{\partial \delta}} + \underset{(-)}{\frac{\partial X^*}{\partial p_x^*}}\,\underset{(+)}{\frac{dp_x^*}{d\delta}} + \underset{(-)}{\frac{\partial X^*}{\partial w^o}}\,\underset{(+)}{\frac{\partial w^o}{\partial p_x^*}}\,\underset{(+)}{\frac{dp_x^*}{d\delta}} \tag{40}$$

It is straightforward to show that the last two terms on the right dominate. The first term is positive as a result of the fall in price elasticity among the richer population. As their incomes rise, these individuals consume more of the drug. The last two terms are the direct and indirect results of the increase in the equilibrium price. The indirect effect is the rise in minimum income requirement to purchase the drug, which in turn lowers demand. As explained above, this mainly affects individuals whose incomes were initially only marginally above the requirement. The direct effect affects everyone. Equilibrium demand for the pharmaceutical decreases with income dispersion.

The effect of increasing dispersion on the equilibrium demand for other goods *Y** is (holding p_y constant):

$$Y^* = Y[\delta, w^o(p_x^*(\delta))]$$

$$\frac{dY^*}{d\delta} = \underset{(+)}{\frac{\partial Y^*}{\partial \delta}} + \underset{(-)}{\frac{\partial Y^*}{\partial w^o}}\,\underset{(+)}{\frac{\partial w^o}{\partial p_x^*}}\,\underset{(+)}{\frac{dp_x^*}{d\delta}} \tag{41}$$

(41) is positive. In words, increasing dispersion increases the demand for other goods. Intuitively, income dispersion forces individuals to substitute away from the luxury good and

towards the necessity good. Thus, the wealth expansion path with an exogenous increase in dispersion is not parallel to the original. Rather, it shifts upward and rotates away from the luxury good, as in Figure 15.

B. Model 2: Uniform Distribution as a Mean Preserving Spread

In this section, I consider a modification of the dispersion presented above. In addition to increasing the upper bound, I also decrease the lower bound of income by δ. See Figure 10. This case may describe the analogy between Sweden and the United Kingdom. Both countries have similar per capita incomes, but Sweden's Gini coefficient is higher than the UK's by 11 points. The average Swedish pharmaceutical price is higher.[6]

Income Distribution:

The new distribution takes the form:

$$h(w) = \frac{1}{w^u - w^l + 2\delta}, \quad (w^l - \delta) \leq w \leq (w^u + \delta) \tag{42}$$

h(w) is a mean preserving spread of the function *f(w)*, which is identical to (25):

$$f(w) = \frac{1}{w^u - w^l}, \quad 0 \leq w^l \leq w \leq w^u \tag{43}$$

H(w) is the cumulative distribution of *h(w)*. *F(w)* second order stochastically dominates

[6]IMS Health.

H(w) since:

$$\int_{w} F(w)\,dw \;\leq\; \int_{w} H(w)\,dw \qquad \forall w \tag{44}$$

Thus, *F(w)* is preferred to *H(w)*. See Figure 11. The Lorenz curve associated with *F(w)* is everywhere higher than the Lorenz curve associated with *H(w)*. That is, we have Lorenz dominance.[7]

Aggregate demand under *H(w)* is:

$$\begin{aligned}
X(p_x, w, \delta) &= \int_{w^l-\delta}^{w^u+\delta} X_i(w)\,dH(w) \\
&= \int_{w^l-\delta}^{w^o} X_i(w)\,dH(w) + \int_{w^o}^{w^u+\delta} \frac{1}{w^u - w^l + 2\delta}\,\frac{\alpha}{\alpha+\beta}\left(\frac{w - w^o}{p_x}\right) dw \\
&= 0 + \frac{1}{(w^u - w^l + 2\delta)p_x}\,\frac{\alpha}{\alpha+\beta}\left(\frac{w^2}{2} - w w^o\right)\Big|_{w^o}^{w^u+\delta} \\
&= \frac{1}{(w^u - w^l + 2\delta)p_x}\,\frac{\alpha}{\alpha+\beta}\left[\frac{(w^u+\delta)^2}{2} - (w^u+\delta)w^o - \frac{w^{o2}}{2} + w^{o2}\right] \\
&= \frac{\alpha}{\alpha+\beta}\,\frac{(w^u + \delta - w^o)^2}{2(w^u - w^l + 2\delta)p_x}, \qquad w^l - \delta < w^l < w^o
\end{aligned} \tag{45}$$

Note that when δ is zero, the resulting expression is the aggregate demand under the superior distribution, *F(w)*.

[7]Atkinson (1970).

Profit Maximization:

Using (45), I maximize profits with respect to price: (and noting that $\frac{dw^o}{dp_x} = \frac{\beta C}{\alpha} = \frac{w^o}{p_x}$)

$$\pi = (p_x - m)X(p_x, w, \delta) - F$$

$$= \frac{\alpha}{\alpha + \beta}\frac{1}{2(w^u - w^L + 2\delta)}\left(\frac{p_x - m}{p_x}\right)(w^u + \delta - w^o)^2 - F \tag{46}$$

$$\frac{d\pi}{dp_x} = \frac{\alpha}{\alpha + \beta}\frac{1}{2(w^u - w^L + 2\delta)}\left[\frac{m}{p_x^2}(w^u + \delta - w^o)^2 + 2(w^u + \delta - w^o)\left(-\frac{dw^o}{dp_x}\right)\left(\frac{p_x - m}{p_x}\right)\right]$$

$$= \frac{\alpha}{\alpha + \beta}\frac{w^u + \delta - w^o}{2(w^u - w^L + 2\delta)p_x^2}[m(w^u + \delta - w^o) - 2w^o(p_x - m)] \tag{47}$$

$$= \frac{\alpha}{\alpha + \beta}\frac{w^u + \delta - w^o}{2(w^u - w^L + 2\delta)p_x^2}[m(w^u + \delta + w^o) - 2w^o p_x]$$

Setting (47) equal to zero and substituting $w^o = \frac{\beta C}{\alpha}p_x$, I get two equilibrium prices:

$$p_x^o(\delta) = \frac{\alpha(w^u + \delta)}{\beta C} \tag{48}$$

$$p_x^{(}(\delta) = \frac{m}{4} + \frac{1}{2}\left(\frac{m^2}{4} + \frac{2m\alpha(w^u + \delta)}{\beta C}\right)^{\frac{1}{2}} \tag{49}$$

(48) and (49) are identical to the equilibrium prices of the model presented in section II ((36) and (37)). Thus, (49) is increasing and concave in δ. (See (38) and Figure 9).

The effect of increasing dispersion on equilibrium demand is not qualitatively different from that in the previous model. That is, dispersion decreases aggregate demand for X and increases aggregate demand for Y. Although this model compares two income distributions with the same mean, it is straightforward to show that when increasing the upper limit of income, the mean income rises. Thus, the equilibrium price (48) is an increasing function of per capita income.

C. Model 3: Mean Preserving Spread

For simplicity, I set $w^l = 0$.

Income Distribution:

Suppose the distribution of income is given by the following function:

$$f(w,\theta) = \begin{cases} \dfrac{\theta}{3w^u}, & 0 \leq w < \dfrac{1}{4}w^u \\ \dfrac{6-\theta}{3w^u}, & \dfrac{1}{4}w^u \leq w < \dfrac{3}{4}w^u, \qquad \theta \in [0,6] \\ \dfrac{\theta}{3w^u}, & \dfrac{3}{4}w^u \leq w < w^u \end{cases} \tag{50}$$

θ is the measure of dispersion. For example, if $\theta = 2$, then the distribution is a step function. If $\theta = 3$, then the distribution is uniform. Thus, as θ increases, inequality increases. The mean and total income under both distributions is the same. Figures 12a-c show that as inequality increases, the mass on both ends of the distribution increases, and the mass in the middle decreases. That is, as inequality rises, the middle-income class shrinks while the low- and upper-income classes grow. This describes what is happening in developing countries, such as Mexico, Brazil, and South Africa, where the middle class owns less than 13% of total income.[8]

F(w, 2) second order stochastically dominates *F(w, 3)* because:

$$\int_{w} F(w,2)\, dw \;\leq\; \int_{w} F(w,3)\, dw \qquad \forall w \tag{51}$$

See Figure 13. The Lorenz curve associated with *F(w,2)* is everywhere higher than the Lorenz curve associated with *F(w,3)*. That is, we have Lorenz dominance.[9]

Because $f(w, \theta)$ is a step function, aggregate demand will have kinks. Aggregate demand is:

[8] World Bank, 2001.
[9] Atkinson (1970).

$$X(p,\theta) \;=\; \int_0^{w^u} X_i(w)\, dG(w)$$

$$= \int_{w^o}^{\frac{1}{4}w^u} \frac{\theta}{3w^u}\frac{\alpha}{\alpha+\beta}\left(\frac{w-w^o}{p_x}\right)dw + \int_{\frac{1}{4}w^u}^{\frac{3}{4}w^u} \frac{6-\theta}{3w^u}\frac{\alpha}{\alpha+\beta}\left(\frac{w-w^o}{p_x}\right)dw$$

$$+ \int_{\frac{3}{4}w^u}^{w^u} \frac{\theta}{3w^u}\frac{\alpha}{\alpha+\beta}\left(\frac{w-w^o}{p_x}\right)dw$$

$$= \frac{\alpha}{\alpha+\beta}\frac{\theta}{3w^u p_x}\left(\frac{w^2}{2}-ww^o\right)\Bigg|_{w^o}^{\frac{1}{4}w^u} + \frac{\alpha}{\alpha+\beta}\frac{6-\theta}{3w^u p_x}\left(\frac{w^2}{2}-ww^o\right)\Bigg|_{\frac{1}{4}w^u}^{\frac{3}{4}w^u}$$

$$+ \frac{\alpha}{\alpha+\beta}\frac{1}{3w^u p_x}\left(\frac{w^2}{2}-ww^o\right)\Bigg|_{\frac{3}{4}w^u}^{w^u} \qquad \textbf{(52)}$$

$$= \frac{\alpha}{\alpha+\beta}\frac{\theta}{3w^u p_x}\left(\frac{w^{u2}}{32}-\frac{w^u w^o}{4}-\frac{w^{o2}}{2}+w^{o2}\right)$$

$$+ \frac{\alpha}{\alpha+\beta}\frac{6-\theta}{3w^u p_x}\left(\frac{9w^{u2}}{32}-\frac{3w^u w^o}{4}-\frac{w^{u2}}{32}+\frac{w^u w^o}{4}\right)$$

$$+ \frac{\alpha}{\alpha+\beta}\frac{\theta}{3w^u p_x}\left(\frac{w^{u2}}{2}-w^u w^o-\frac{9w^{u2}}{32}+\frac{3w^u w^o}{4}\right)$$

$$= \frac{\alpha}{\alpha+\beta}\frac{1}{6w^u p_x}\left(3w^{u2}-6w^u w^o+\theta w^{o2}\right), \qquad 0 < w^o < \tfrac{1}{4}w^u$$

Profit Maximization:

Profits are maximized with respect to p_x:

$$\pi(\theta) = (p_x - m)X(p,\theta) - F$$

$$= \frac{\alpha}{\alpha + \beta}\frac{1}{6w^u}(\frac{p_x - m}{p_x})(3w^{u^2} - 6w^u w^o + \theta w^{o^2}) - F \tag{53}$$

$$\frac{d\pi}{dp_x} = \frac{\alpha}{\alpha + \beta}\frac{1}{6w^u}[\frac{m}{p_x^2}(3w^{u^2} - 6w^u w^o + \theta w^{o^2}) + (-6w^u\frac{dw^o}{dp_x} + 2\theta w^o\frac{dw^o}{dp_x})(\frac{p_x - m}{p_x})$$

$$= \frac{\alpha}{\alpha + \beta}\frac{1}{6w^u p_x^2}[m(3w^{u^2} - 6w^u w^o + \theta w^{o^2}) + (-6w^u w^o + 2\theta w^{o^2})(p_x - m) \tag{54}$$

$$= \frac{\alpha}{\alpha + \beta}\frac{1}{6w^u p_x^2}[3mw^{u^2} - \theta m w^{o^2} + p_x(2\theta w^{o^2} - 6w^u w^o)])$$

Setting (54) equal to zero and substituting $w^o = \frac{\beta C}{\alpha}p_x$, I get the cubic function:

$$2\theta(\frac{\beta C}{\alpha})^2 p_x^3 - (\theta m\frac{\beta C}{\alpha} + 6w^u)\frac{\beta C}{\alpha}p_x^2 + 3mw^{u^2} = 0 \tag{55}$$

Cubic functions are difficult to solve. Because I am mainly interested in how inequality affects the equilibrium price, I apply the implicit function theorem. Let (55) be called the function *A*, and the effect of inequality on price is:

$$\frac{dp_x}{d\theta} = -\frac{\frac{\partial A}{\partial \theta}}{\frac{\partial A}{\partial p_x}} = -\frac{2(\frac{\beta C}{\alpha})^2 p_x^3 - m(\frac{\beta C}{\alpha})^2 p_x^2}{6\theta(\frac{\beta C}{\alpha})^2 p_x^2 - 2\theta m(\frac{\beta C}{\alpha})^2 p_x - 12 w^u (\frac{\beta C}{\alpha}) p_x}$$

$$= \frac{(2p_x - m)p_x}{12\frac{\alpha w^u}{\beta C} + 2\theta(m - 3p_x)} > 0$$

(56)

$$\frac{d^2 p_x}{d\theta^2} = \frac{(4p_x \frac{dp_x}{d\theta} - m\frac{dp_x}{d\theta})(12\frac{\alpha w^u}{\beta C} + 2\theta m - 6\theta p_x) + 6\theta\frac{dp_x}{d\theta}(2p_x^2 - mp_x)}{(12\frac{\alpha w^u}{\beta C} + 2\theta m - 6\theta p_x)^2}$$

$$= \frac{(4p_x - m)(12\frac{\alpha w^u}{\beta C} + 2\theta m - 6\theta p_x) + 6\theta(2p_x^2 - mp_x)}{(12\frac{\alpha w^u}{\beta C} + 2\theta m - 6\theta p_x)^2}\frac{dp_x}{d\theta} > 0$$

Equilibrium price is increasing and convex in inequality. See Figure 14.

The effect of increasing dispersion is the same as the previous models. Dispersion decreases aggregate demand for X and increases aggregate demand for Y.

V. Summing Up

In all three models presented, the common result is that dispersion increases the equilibrium price of a pharmaceutical. The effect of the increase in dispersion rotates the budget lines in Figure 2 inwards (the pharmaceutical is relatively more expensive now). The result is an upward shift of the wealth expansion path (although this is not a parallel shift since consumption of X decreases). This effect is shown in Figure 15.

In all the models, the rise in equilibrium price penalizes the poor. The effect on the rich, however, deserves a different interpretation. The first two models show that the equilibrium price is concave in dispersion. The third model shows price to be convex in dispersion. Relative to model 3, models 1 and 2 protect the rich. Price increases are relatively smaller as the rich get richer.

In the context of multiple countries, the price of a pharmaceutical as developed in this paper depends on two development characteristics: per capita income and income inequality. When either increases, so does the equilibrium price. The former result corroborates empirical findings on the statistically significant effect of per capita income on drug prices. The latter result has not been empirically tested. The results from this paper are, however, conducive to nonlinear regression techniques so that income inequality may be tested as a source of variation of drug prices across countries. It is this endeavor which I undertake in my next chapter.

References:

Atkinson, A.B. 1970. "On the measurement of inequality," *Journal of Economic Theory* 2 (3): 244-63.

Castro-Leal, F., J. Dayton, L. Demery, & K. Mehra. 2000. "Public spending on health care in Africa: do the poor benefit?" *Bulletin of the World Health Organization* 78 (1):66-74.

Feachem, Richard G., et al. 1992. *The health of adults in the developing world*. A World Bank Book. Oxford University Press: New York.

Hunter, Linda C., and James R. Markusen. 1988. "Per-capita income as a determinant of trade," in *Empirical Methods for International Trade*, edited by Robert C. Feenstra. MIT Press: Cambridge.

Makinen, M., H. Waters, M. Rauch, N. Almagambetova, R. Bitran, L. Gilson, D. McIntyre, S. Pannarunothai, A.L. Prieto, G. Ubilla, & S. Ram. 2000. "Inequalities in health care use and expenditures: empirical data from eight developing countries and countries in transition," *Bulletin of the World Health Organization* 78 (1): 55-65.

Mapelli, Vittorio. 1993. "Health needs, demand for health services and expenditure across social groups in Italy: An empirical investigation," *Social Science and Medicine* 36 (8):999-1009.

World Bank. 2001. *World Bank Development Indicators*.

Appendix

Effects of increasing dispersion on: (relative to benchmark distribution)

	Model 1 (δ)	Model 2 (δ)	Model 3 (θ)
Mean income	increasing	constant	constant
Total wealth	increasing	constant	constant
Upper income limit	increasing	increasing	constant
Lower income limit	constant	decreasing	constant
p_x^*	increasing, concave	increasing, concave	increasing, convex
$X(p,w,\delta,\theta)$	decreasing	decreasing	decreasing
$Y(p,w,\delta,\theta)$	increasing	increasing	increasing
$X(p,w,\delta,\theta)/Y(p,w,\delta,\theta)$	decreasing	decreasing	decreasing
Type of dispersion:	first-order stochastic dominance	mean-preserving spread	mean-preserving spread

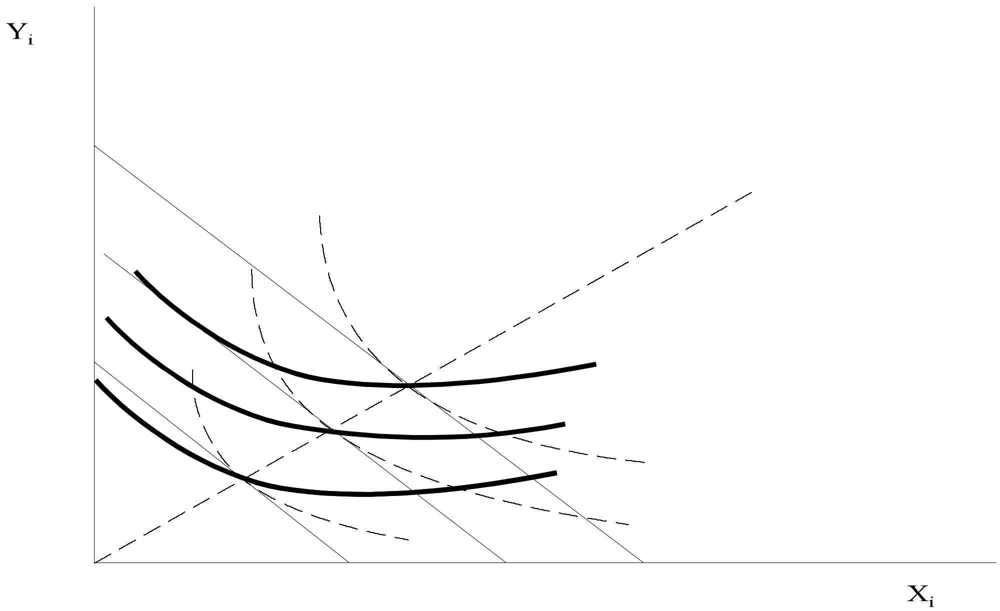

Figure 1: Comparing indifference curves with homothetic (dotted) and non-homothetic (solid) preferences

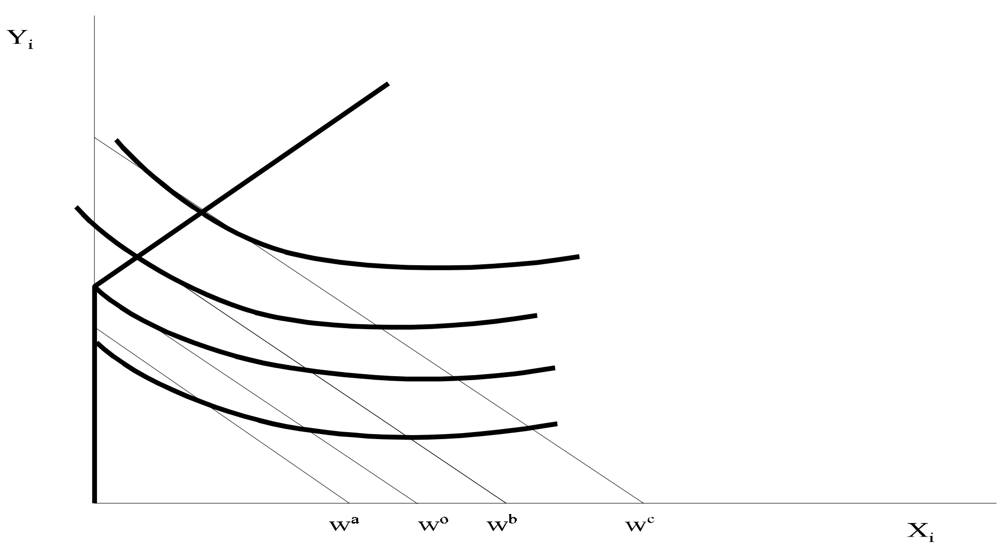

Figure 2: Indifference curves with non-homothetic preferences

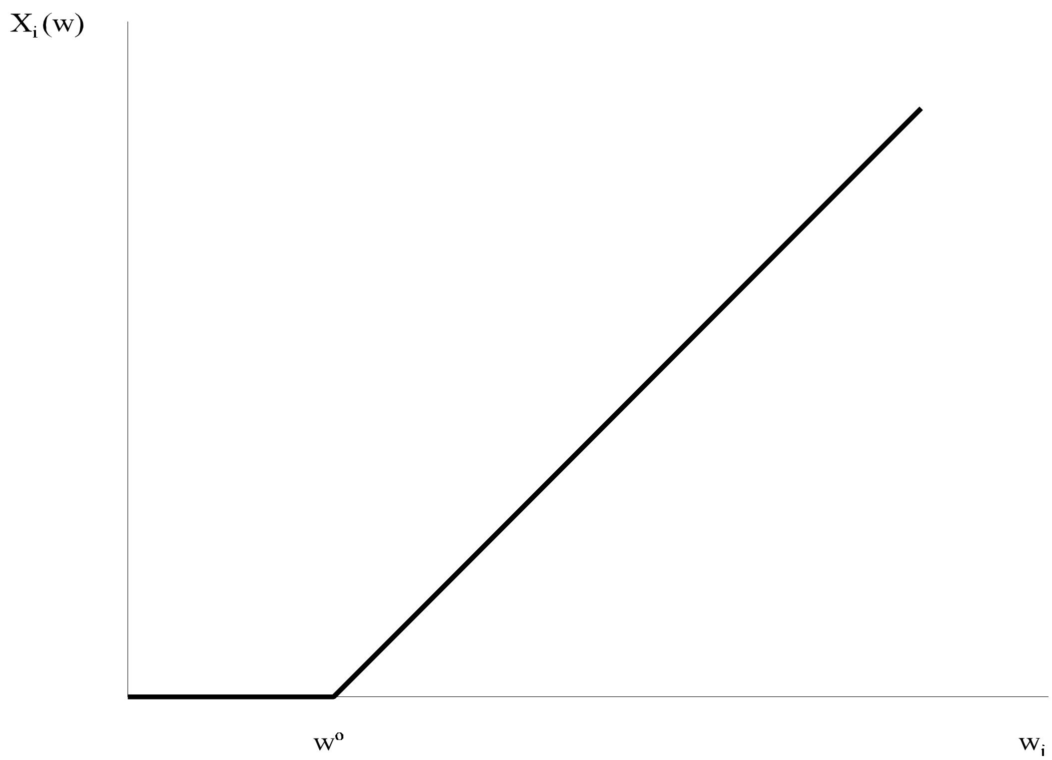

Figure 3: Engel curve

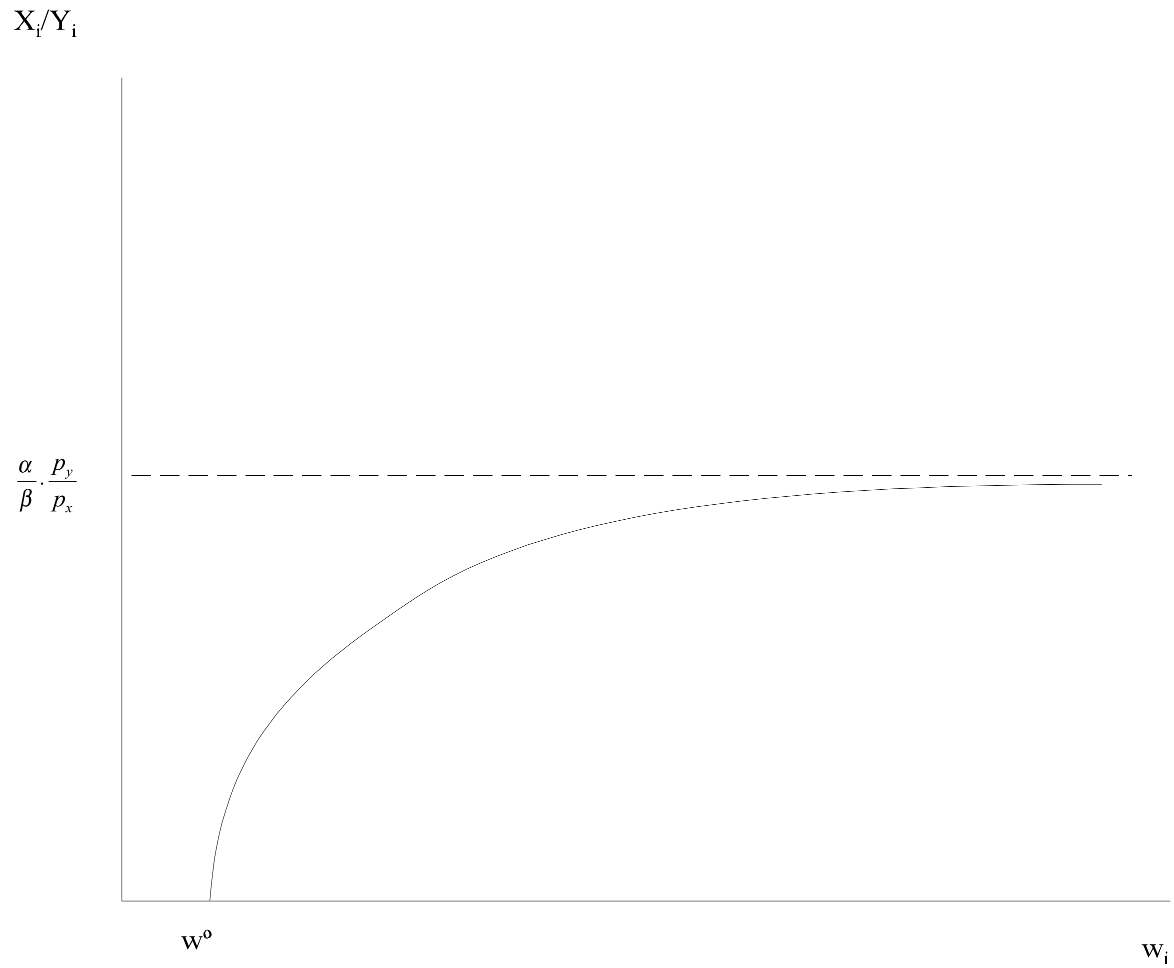

Figure 4

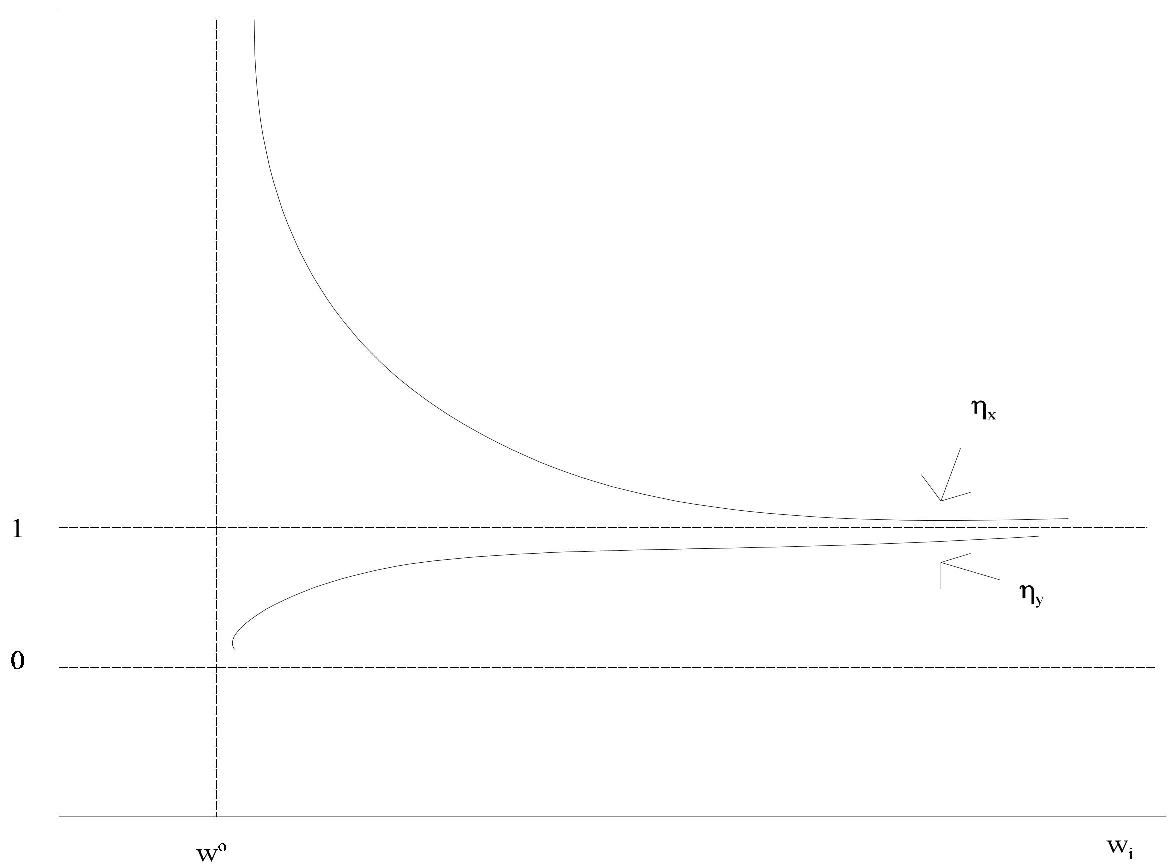

Figure 5: Income elasticities of demand

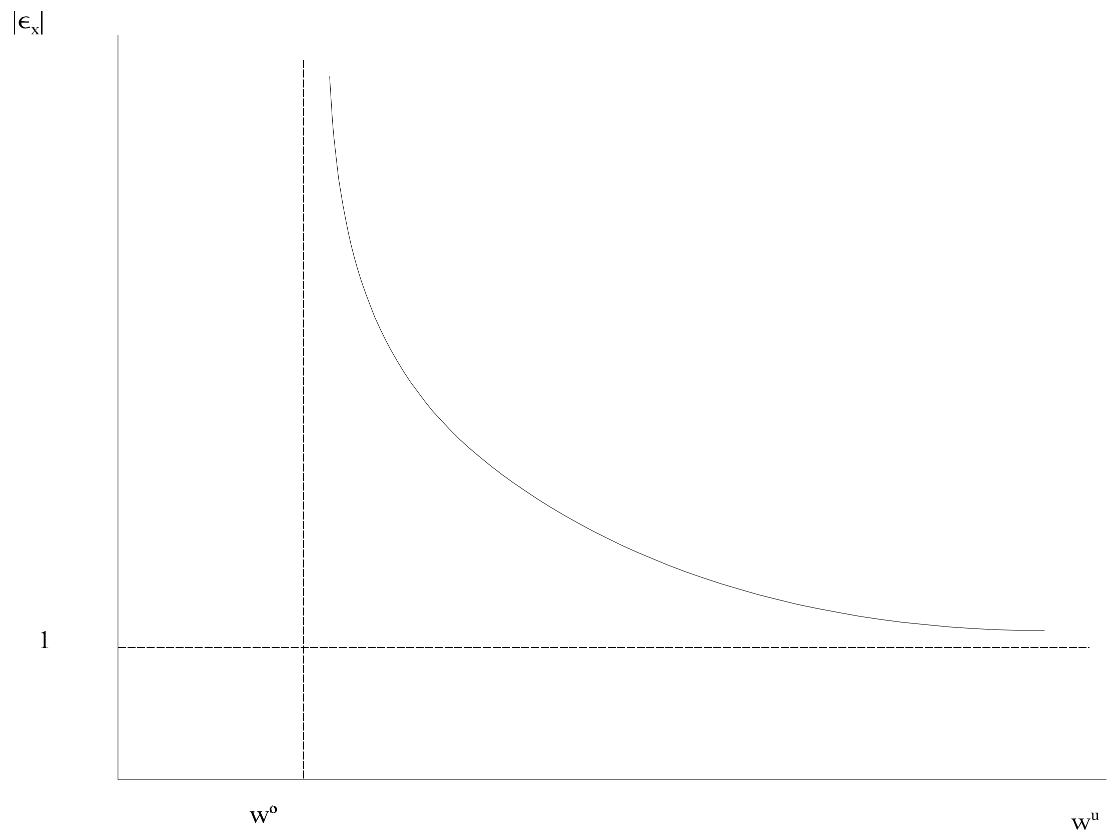

Figure 6: Price elasticity of demand for pharmaceuticals

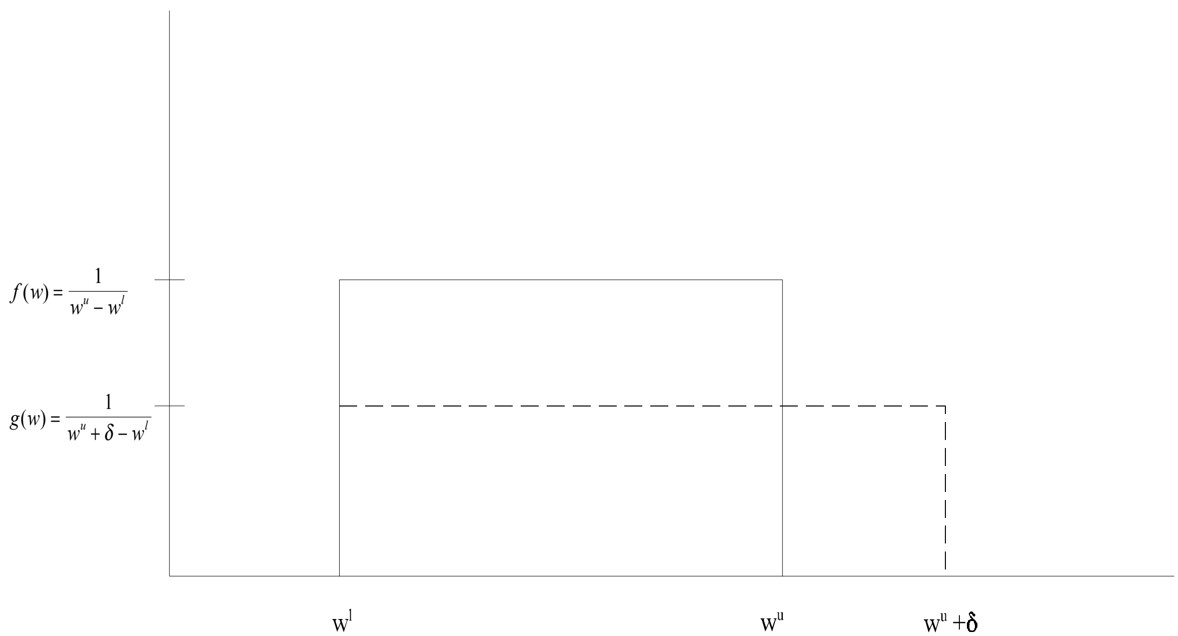

Figure 7: Model 1– Income Distribution

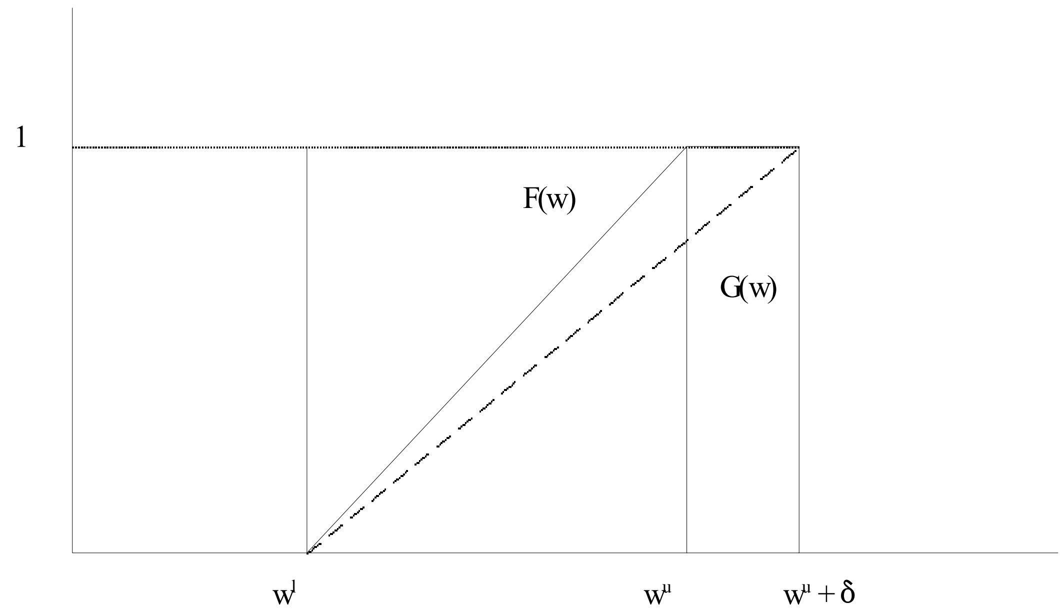

Figure 8: Model 1– G(w) first order stochastically dominates F(w)

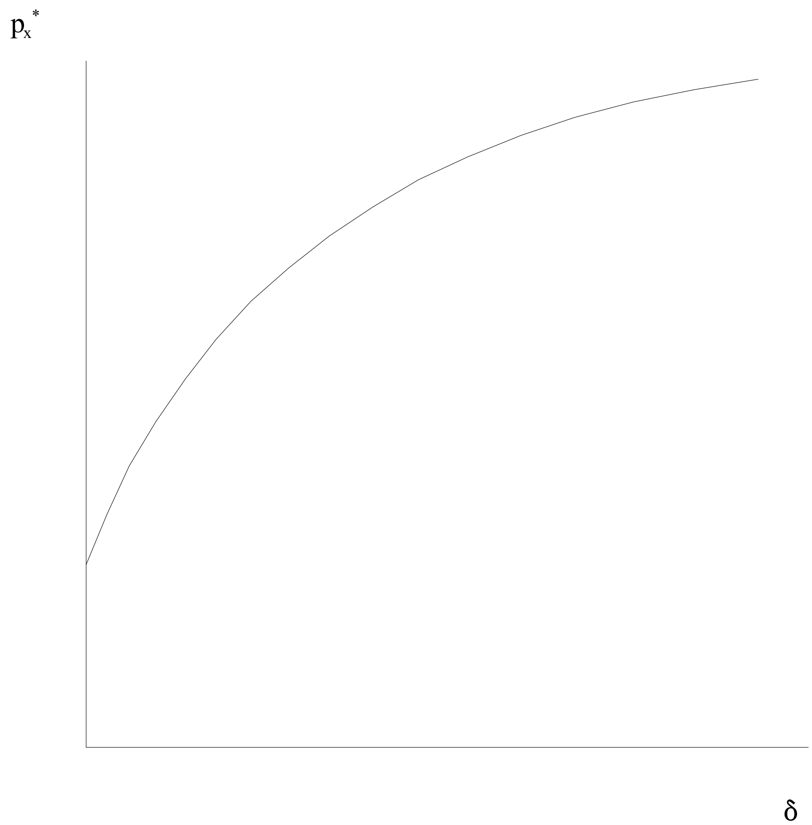

Figure 9: Models 1 and 2– The effect of dispersion on equilibrium price of pharmaceuticals

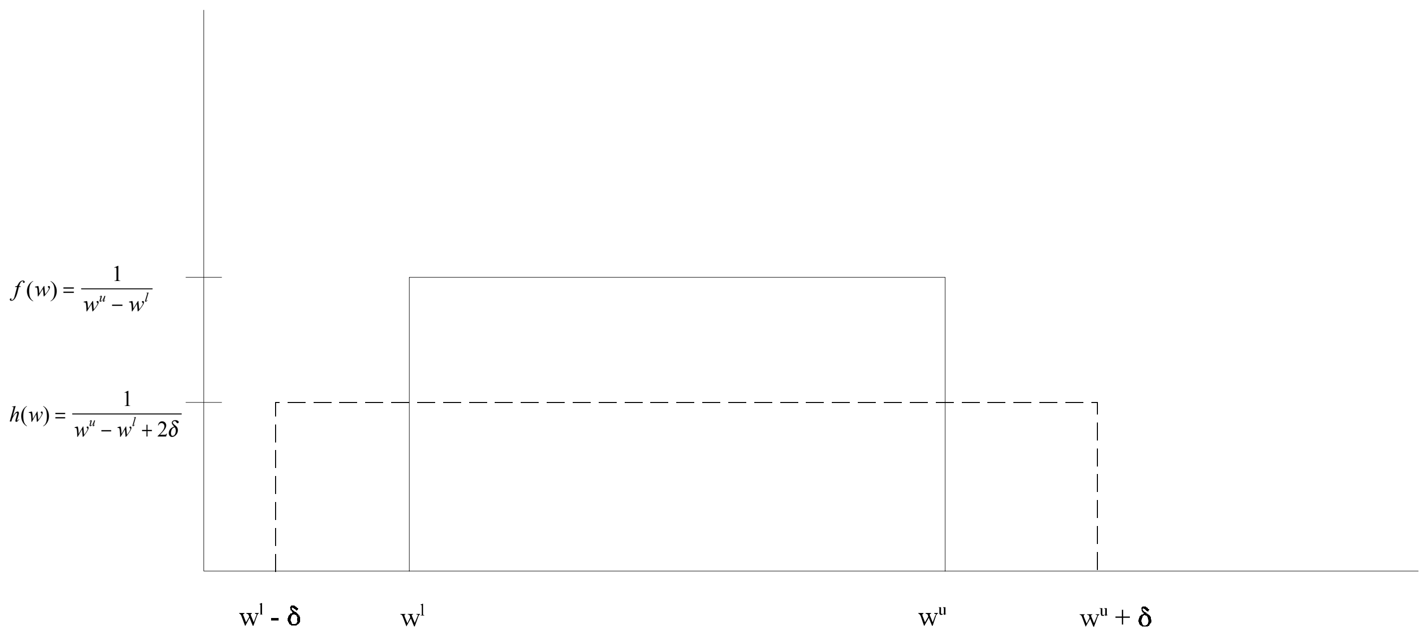

Figure 10: Model 2 – Income Distribution

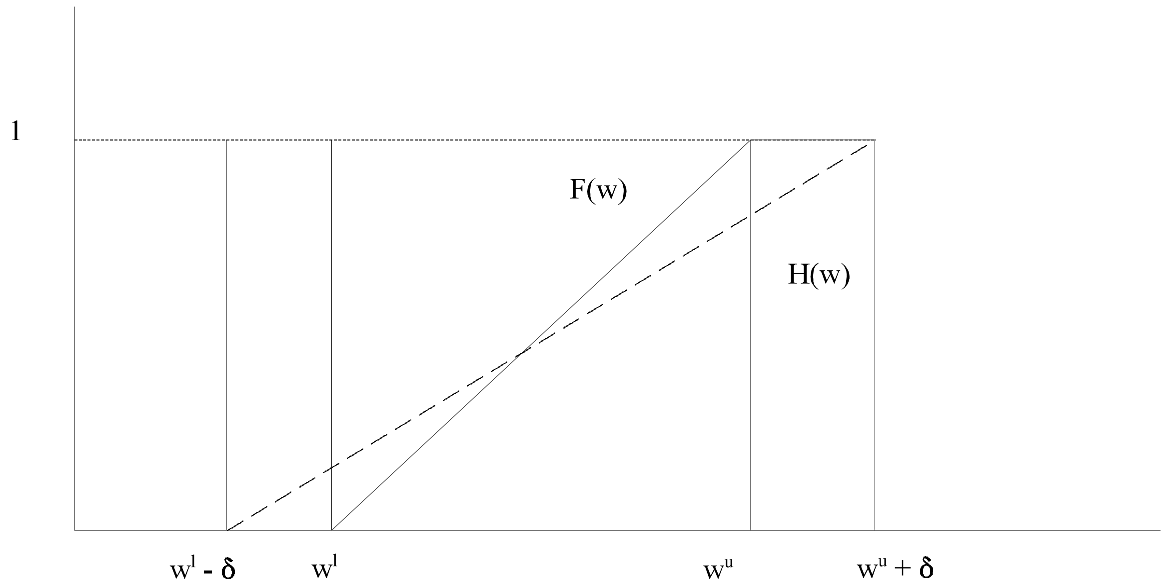

Figure 11: Model 2 – F(w) second order stochastically dominates H(w)

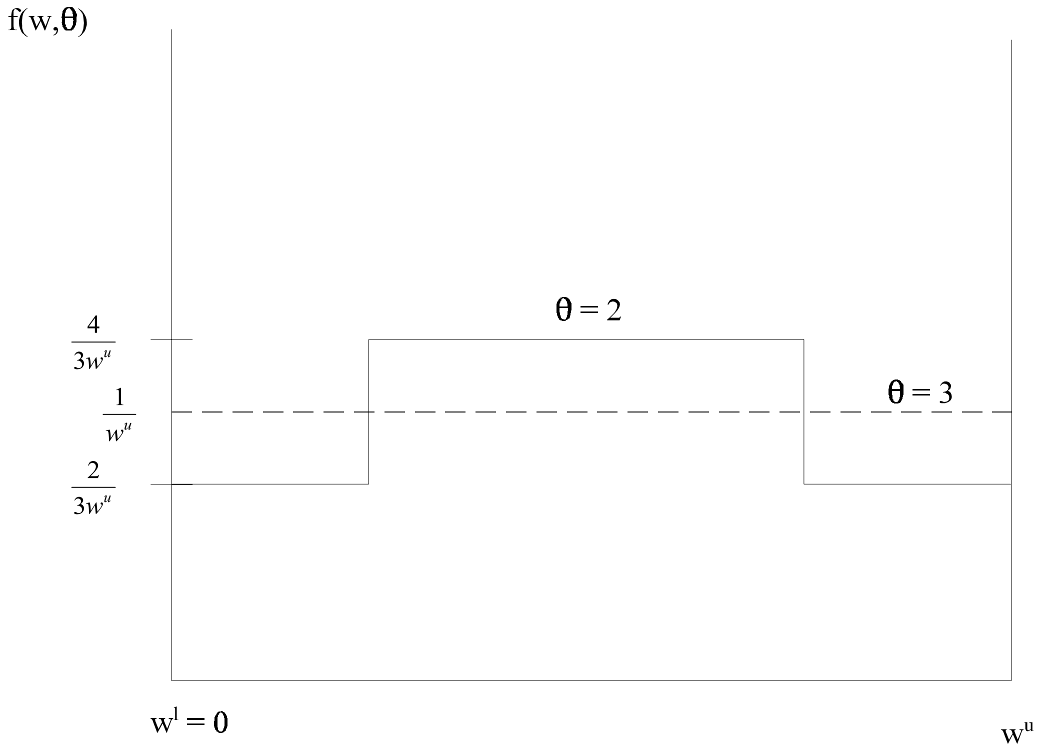

Figure 12a: Model 3 – Income Distribution

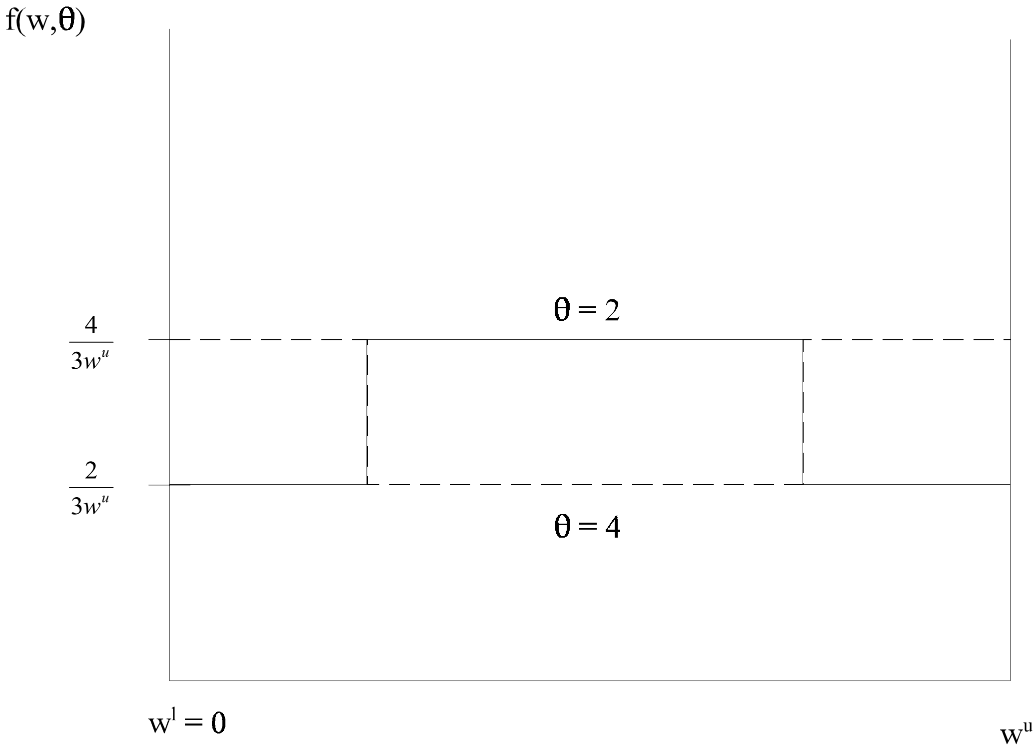

Figure 12b: Model 3 – Income Distribution

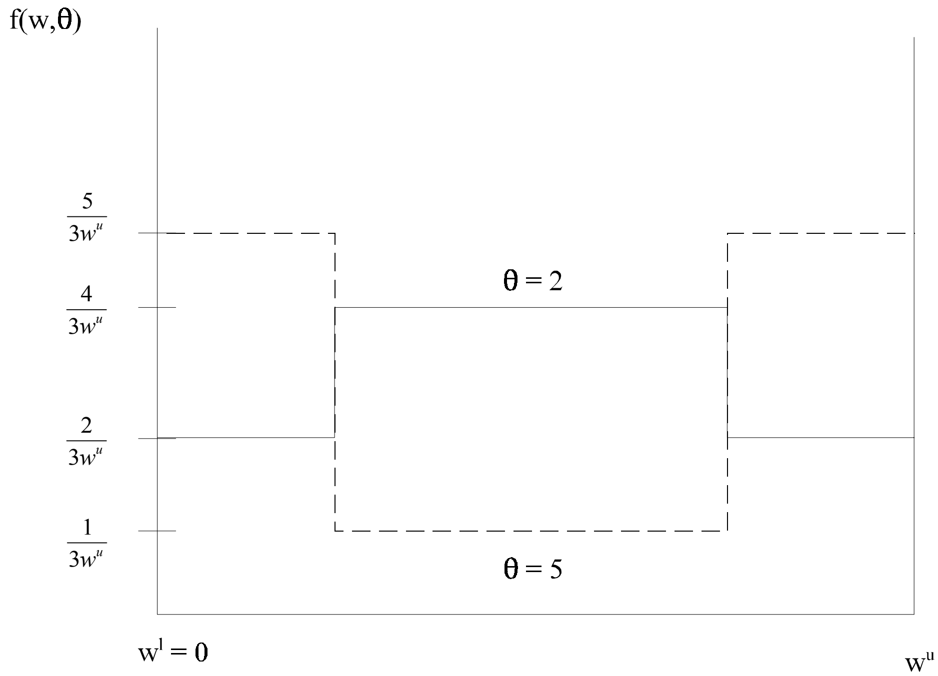

Figure 12c: Model 3 – Income Distribution

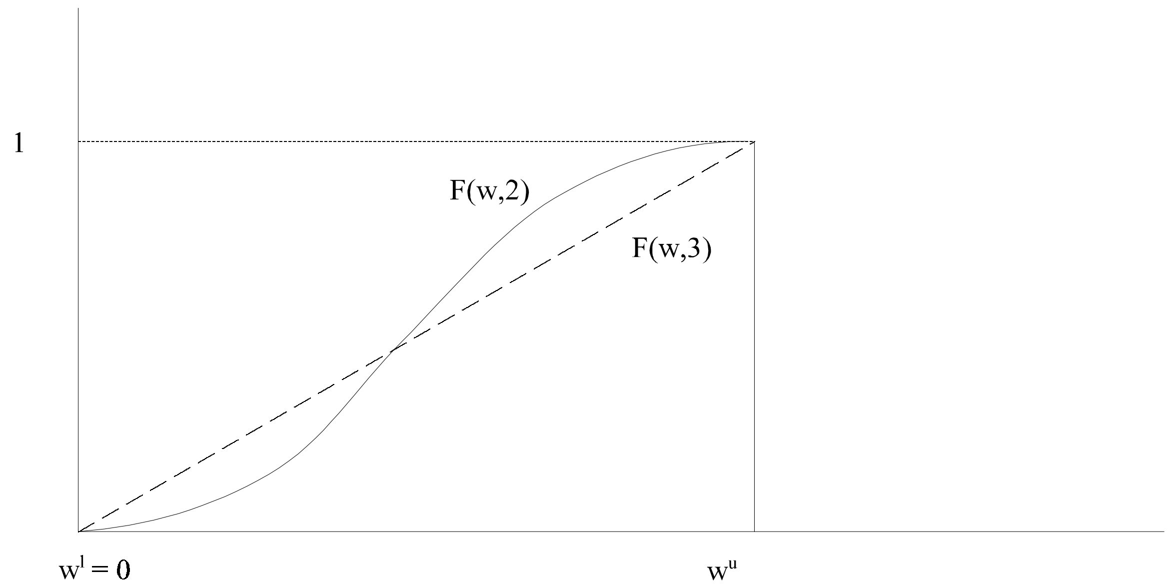

Figure 13: Model 3 – F(w, 2) second order stochastically dominates F(w, 3)

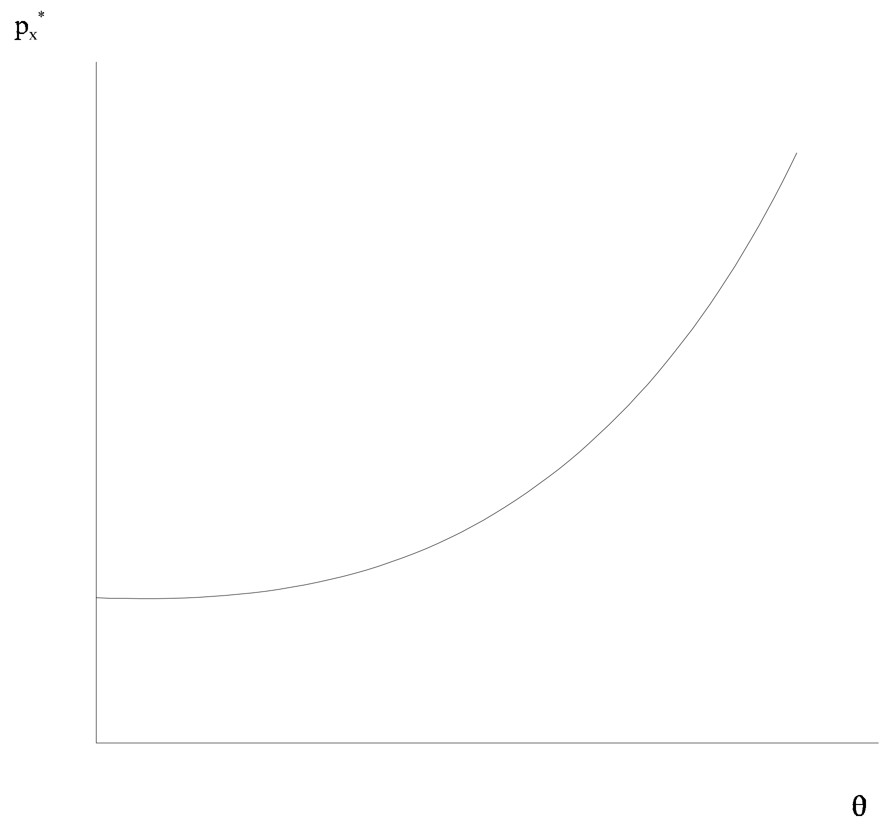

Figure 14: Model 3 – The effect of dispersion on equilibrium price of pharmaceuticals

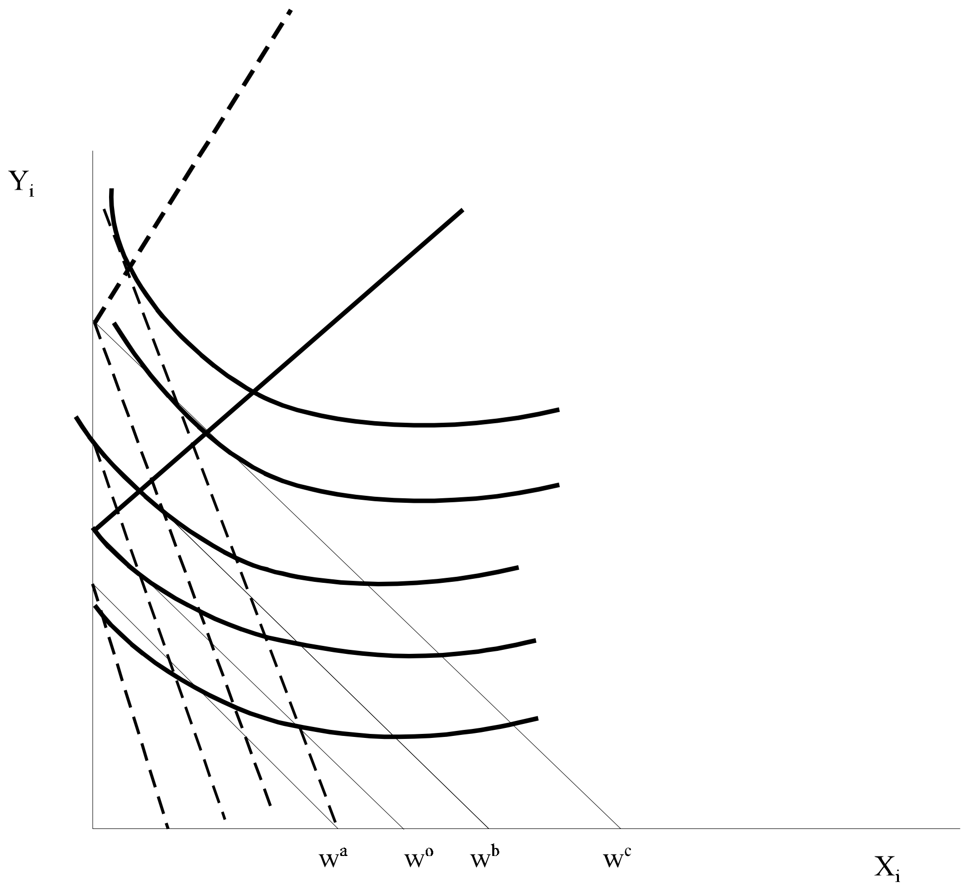

Figure 15: Effect of increasing dispersion on wealth expansion path