A General-Equilibrium Analysis of Public Policy for Pharmaceutical Prices

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Abstract

Retail sales of prescription drugs totaled $154.5 billion in 2001. The National Institute for Health Care Management estimates annual sales will exceed $400 billion by the year 2010. This paper analyzes the welfare and distributional effects of two policy families that could be used to cope with high and rising pharmaceutical costs. We employ a general-equilibrium approach to contrast the current patented-monopoly system with a) a price ceiling imposed on the pharmaceutical sector of the economy; and b) a universal insurance program covering pharmaceutical purchases. We use a version of the Kelton and Wallace (1995) monopoly production environment: a two-good general-equilibrium model in which a license is required to produce one of the goods. Individuals in the model are heterogeneous with respect to preferences, but have identical production technologies and labor resources. Results indicate potential welfare gains for both the price-ceiling and universal-insurance policies, with very distinct distributional effects.

Key words: Drug prices, pharmaceutical markets, general equilibrium, social welfare, prescription drug insurance.

JEL codes: I11, I18, D42, D6, H2

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1. Introduction

The current pharmaceutical system of patented monopoly attempts to balance the immediate interests of patients and third-party payers (who want low-cost medicines) with higher prices and profits for the pharmaceutical companies. This system grants innovative pharmaceutical companies twenty-year patents that bestow monopoly status on the innovators.[1] The profits earned during the life of the patent encourage the development of new drugs, and of new drug forms, by the firms. In fact, the average cost of bringing a new drug to markets is estimated to be over $800 million.[2] Without the opportunity to be rewarded for their efforts, drug companies would not undertake the risks associated with developing new drugs.

However, for several years now, skyrocketing pharmaceutical costs have put the current system under tremendous pressure. Although the cost of drug innovation has risen substantially over the last decade (according to DiMasi, *et al.*, 2003, research and development costs have risen annually at the rate of 7.4 percent above inflation), this rising expense alone cannot account for the double-digit annual pharmaceutical cost increases. The private sector is responding to the rising costs of pharmaceuticals through the use of drug formularies, the emergence of pharmaceutical-benefit management companies and the expansion of mail-order pharmacies. In the public sector, state Medicaid programs are adopting prior authorization programs for more expensive drugs and either require or encourage substitution of generic drugs in an attempt to slow their soaring expenditures. Drug acquisition costs for Medicaid are reduced further by rebates given by the pharmaceutical manufacturers.[3] Medicare reform hopes to offer relief to the elderly (who account for a very large share of prescription-drug use) through prescription-drug insurance coverage.[4]

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[1] In practice, since patents are generally granted well before a new drug is available to the public, firms hold monopoly status during the first ten or so years the drug is marketed. They do not receive monopoly benefits over the full twenty-year patent life.

[2] DiMasi *et al.* (2003), in a study initially prepared for the Tufts Center for the Study of Drug Development, estimates the average research and development cost of new pharmaceutical products to be $802 million. This estimate includes the cost of project failures, lengthy trial periods and a variety of other issues.

[3] See the Kaiser Commission on Medicaid and the Uninsured (2002), *Medicaid Outpatient Prescription Drug Benefits: Findings from a National Survey and Selected Case Study Highlights.*

[4] Section 101 of the Medicare Prescription Drug, Improvement, and Modernization Act of 2003 (commonly known as the "2003 Medicare Reform Act") establishes a standard benefit for enrollees in Medicare-funded drug plans, as of January 2006: a deductible of $250; plan payment of 75 percent of drug costs up to $2,250; no coverage from $2,250 to $5,100; and catastrophic coverage thereafter with a small co-pay. There is also an annual out-of-pocket limit of $3600. See the United States Chamber of Commerce (2003), Summary of "Medicare Prescription Drug, Improvement, and Modernization Act of 2003" Public Law No. 108-13 (the "Act").

There are two types of public policy studies that should be undertaken prior to implementation of new public policy toward pharmaceuticals. The first type looks at and compares the theoretical welfare, distributional and efficiency implications of proposed policies and policy forms. The second empirically evaluates welfare, distributional and efficiency consequences in the context of a particular institutional framework and determines specifics such as optimal copayment and deductible levels.

To be sure, before passage of the 2003 Medicare Reform Act, several detailed economic analyses of the second type were undertaken. Both an October 2002 Congressional Budget Office report (CBO, 2002) and a 2003 Commonwealth Fund report (Collins, Davis and Lambrew, 2003) empirically evaluate welfare, distributional, cost and efficiency consequences of various versions of a Medicare prescription drug benefit. However, these studies were undertaken within the context of the current Medicare framework in order to extend this framework to cover pharmaceutical purchases by the elderly. Unfortunately, due to the rush to provide some form of coverage as quickly as possible, the first type of economic analysis was not undertaken. Indeed, to our knowledge, no economic analyses have focused on the optimal form for government policy with respect to pharmaceutical coverage. Our work goes some way to filling this gap.

In this paper, by means of general-equilibrium analysis, we compare the welfare and distributional effects of two alternative policy families often proposed for coping with high and rising expenditures on pharmaceuticals: price ceilings (as a means of cost containment) and universal prescription drug insurance (as a means of protecting high-need users).[5] We explore these policies in the context of a monopolistic market structure; we do not consider alternative market structures, such as perfect competition, that could lead to considerably less innovative drug development. Although variants of both policies can enhance social welfare relative to the current system, they lead to distinct distributional effects. Our goal is to be able to offer general policy guidance with respect to pharmaceutical prices and costs by evaluating and comparing public policy families.

High and Rising Pharmaceutical Expenditures

In the United States, health-care-related expenditures have reached an historical high, both in an absolute sense and as a share of gross domestic product. The aging of the U.S. population

[5]We believe the goal of public policy should be to make pharmaceuticals accessible to those who need them most. Thus by "coping" with high pharmaceutical costs we mean making pharmaceuticals affordable for consumers. Policies that achieve this goal may or may not reduce overall public spending on pharmaceuticals and may or may not affect profits received by pharmaceutical producers.

implies this problem will remain at least as severe or, more likely, increase in urgency in the future. Prescription drugs constitute an important component of health care. Retail sales of prescription drugs totaled $154.5 billion in 2001; the Centers for Medicare and Medicaid Services estimate that, by the year 2010, the nation will spend $404.5 billion annually for this purpose. Medicaid spending on prescription drugs tripled during the 1990s from $4.8 billion in 1990 to $17 billion in 1999.[6] Furthermore, according to estimates by the Congressional Budget Office, the new Medicare prescription drug coverage is estimated to cost $400 billion over a ten-year period.[7]

According to a recent report prepared by the National Institute for Health Care Management, the explanations for the rising trend in drug expenditures include declining buyer price sensitivity due to better insurance coverage for drugs; an increase in the number of prescription medicines available, especially for chronic conditions; an increase in the diagnosis of diseases in an aging population; and more aggressive marketing of prescription drugs to doctors and patients.[8] These four factors underlie both an increase in the number of prescriptions written (an increase in drug utilization) and an increase in the average price per prescription. According to statistics available from the Bureau of Labor Statistics, wholesale prices of prescription pharmaceuticals have risen over 250 percent since 1982 (in comparison to the producer price index for all commodities, which rose 40 percent over the same time period).

Accompanying the rising prices is a general rise in quality. Using the Medical Expenditure and Panel Survey data, Lichtenberg (2000) showed that the replacement of older drugs by newer, more expensive drugs was the single most important reason for the increase in the average level of pharmaceutical prices. In addition, he found that the higher price reflects higher quality; that is, the newer, more expensive drugs not only reduce mortality and morbidity rates due to illness, but also reduce the total medical cost of treating the condition.[9]

[6] See The National Institute for Health Care Management (May 2002), *Prescription Drug Expenditures in 2001: Another Year of Escalating Costs.*

[7] See, for example, *CBO Testimony: Estimating the Cost of the Medicare Modernization Act*, March 24, 2004.

[8] The National Institute for Health Care Management (May 2002), *Prescription Drug Expenditures in 2001: Another Year of Escalating Costs.*

[9] We leave to others (for example, see Zweifel, 1990), the ethical issues surrounding the value of extending life or improving the quality of life, especially for the elderly. We do point out here that a significant amount of resources is being devoted to drug purchases. According to *Drug Topics*, a bi-weekly publication for pharmacists, forty-two drugs had retail sales in 2004 alone that topped the estimated $802 million in drug development cost. The top five sellers were Lipitor® at $6.0 billion, Prevacid® at $3.2 billion, Zocor® at $3.2 billion, Nexium® at $3.0 billion, and Zoloft® at $2.6 billion.

Prescription-Drug Markets

Pharmaceutical markets are dynamic. New drugs constantly replace older, less effective medicines. Whole new categories of medicines develop around "blockbusters." Anti-ulcer gastric medications provide an interesting case in point. This market, which did not exist prior to 1977 when Tagamet® was introduced by SmithKline, is now on its third generation of drugs capable of fighting ulcers, with each generation more expensive than the one before. All three generations (histamine H_2-receptor antagonists, coating agents and proton pump inhibitors) are now available simultaneously. Approximately ten different generic compounds loosely compete with each other in this market.

Despite the existence of various types of medication for the same condition, evidence strongly suggests that entry of new branded medications has essentially no effect on the average wholesale price (AWP) of other branded medications in the same therapeutic class and rather little effect on their transaction prices (see Dusing, *et al.*, 2005). In fact, the upward trend in AWP for each of the proton pump inhibitors continues unabated after entry of new medications (see Guo, *et al.*, 2004). The standard prediction of microeconomic models – that price falls with the number of competitors – clearly fails in the case of branded medications. Indeed, due to the unique characteristics of each medication no one of the branded medications is a perfect substitute for any other. Some patients benefit more from some drugs while others benefit more from other drugs. In addition, physicians tend to have their preferred medications. Although pharmacy benefit managers and health maintenance organizations maintain formularies and may encourage the use of less expensive drugs, each patented, branded medication maintains considerable monopoly power.[10] We model the prescription drug sector of the economy as a monopoly. Each patented branded drug has a monopoly, over the life of its patent, in the market for that specific generic compound.[11]

[10] Although our model does not incorporate varying degrees of buyer strength (an omission which should not affect our welfare results qualitatively), we recognize the ability of large hospitals and other classes of buyers to obtain discounts from AWP. Significant buyer power that is used to negotiate price discounts comes from the ability to take advantage of any between-brand competition in a therapeutic class (see Dusing, *et al.*, 2005). For some blockbuster drugs, little if any discounting occurs for any buyer – all buyers essentially pay full price. At the other extreme, Dusing, *et al.* finds that one large hospital buyer was able to obtain 65 percent discounts on some of the older anti-infective medications that it purchased. On average, drugs were discounted for this same hospital buyer 46 percent relative to AWP.

[11] We examine gross monopoly profits, rather than profits net of research and development and other fixed costs of production. Modeling the R & D process itself is beyond the scope of this paper. Our analysis assumes the pharmaceutical firm has already completed its R & D and has made the decision to market a particular pharmaceutical product. Also outside our model are the potential effects of public policy on future innovation. Finkelstein (2003) and Acemoglu and Linn (2003) show that the pace of innovation in a drug market is related to market size. To the extent the policies discussed in this paper affect market size and drug-company profitability, future drug development may be affected. Universal pharmaceutical insurance, by increasing revenues and profits for pharmaceutical companies,

Once patent expiration occurs, our model (along with the concern over the extraordinary cost of the drug) is no longer appropriate. Upon expiration of a branded drug's patents, generic companies provide direct competition to the branded drug company, seriously challenging its market power and bringing down costs for that chemical compound.

A General-Equilibrium Approach

Since our interest is in social welfare and general policy evaluation, we are reluctant to rely on partial-equilibrium analysis. We adopt instead the general-equilibrium monopoly model of Kelton and Wallace (1995). The general-equilibrium model is superior in its accounting for interactions between the monopolistic and nonmonopolistic sectors. In addition, the preferences of all individuals (whether monopoly shareholders or not) are explicitly modeled.

To our knowledge there exist only two other general-equilibrium analyses of public policy toward health care.[12] Bednarek and Pecchenino (2002) uses an overlapping-generations model to assess the general welfare and distributional effects of Medicare and Medicaid. Their model incorporates two types of consumers and two possible types of illness. Canton and Westerhout (1999) develop a general-equilibrium model for the Dutch pharmaceutical market, as part of a larger project to model the entire Dutch health care sector. The behavior of, and interactions between, patients (and physicians acting as "perfect agents" for the patients), pharmacists, drug producers and parallel importers are explicitly modeled. Our model, as described below, shares some of the characteristics of the Canton and Westerhout framework. For example, heterogeneous consumers in both models have different needs for pharmaceutical products. On the other hand, we treat competition quite differently. Whereas Canton and Westerhout model a Stackleberg relationship between a price-leader branded pharmaceutical manufacturer and a follower generic or "me-too" pharmaceutical company, our model focuses specifically on the monopolistic character of patented branded drugs. Furthermore, whereas pharmacists play a key role in the Canton and Westerhout model, they do not in our model. With their drug costs largely determined by pharmaceutical companies (with some room for negotiation for the large drugstore chains), and their revenues determined by third-party payers, pharmacists have little independent role in price determination. In the large hospital

would likely have a positive impact on drug innovation while a price ceiling, by decreasing revenues and profits for pharmaceutical companies, would likely have a negative impact on drug innovation.

[12]There is a long empirical literature dating from Harberger (1954), and followed by Cowling and Mueller (1978) and Littlechild (1981), that seeks to provide an estimate of aggregate deadweight loss (DWL) to the economy resulting from a market's being organized monopolistically as opposed to competitively. See Waldman and Jensen (2001) for a textbook treatment of DWL and other social-welfare costs of monopoly.

sector, in any case, drug purchasers either deal directly with the pharmaceutical manufacturers or work through a group purchasing organization in drug acquisition (see Dusing, *et al.*, 2005).

In the next section we describe a general-equilibrium model of monopoly. We commit ourselves to a particular utility function for the economy's agents in order to ensure tractability. Given a set of values for the model's parameters (obtained by calibration), we numerically compute monopoly price, sales, profits and output. Sections 3 and 4, respectively, describe a price ceiling and a universal drug insurance policy and their equilibria. Section 5 evaluates the policies, comparing them to the current system of patented monopoly. This section also identifies political economy issues that could arise when trying to implement these policies. Section 6 concludes.

2. A Patented Drug Monopoly

The model is a two-good, general-equilibrium model in a production environment.[13] We think of good one as a patented, branded pharmaceutical, while good two is "other goods."[14] We summarize the model in this section. For a more detailed discussion of the model, including comparative statics and a sensitivity analysis, see Kelton and Rebelein (2005).

The Environment

There is a continuum of individuals. Each individual h has equivalent mass and is distinguished by his or her utility parameter ρ_h. All individuals have the same amount of labor resource l. Let l_{1h} and l_{2h} be the amounts of labor h devotes to production of good one and good two, respectively, and let a_1 and a_2 be the respective technological coefficients for good-one and good-two production. The coefficient a_i is the rate, measured in units of good i per unit of labor, at which h can produce good i. Hence, individual h produces an amount of good one equal to $a_1 l_{1h}$ and an amount of good two equal to $a_2 l_{2h}$. Useful later will be the fact that the marginal cost of producing good one, measured in terms of foregone good-two production, equals a_2/a_1.

[13]The model builds on the framework developed by Kelton and Wallace (1995).

[14]Both goods are assumed to be divisible. Although this assumption is not strictly met for some administration forms of pharmaceuticals, namely capsules and tablets, it is certainly realistic for intravenous, inhaled and topical medications.

Each consumer has preferences over the two goods, with (c_{1h}, c_{2h}) denoting individual h's (good one, good two) consumption pair. The utility for individual h is

$$u_h(c_{1h}, c_{2h}) = (c_{1h} + \sigma)^{\rho_h}(c_{2h})^{(1-\rho_h)}, \tag{1}$$

where $\rho_h \in (0, 1)$ varies uniformly across the consumers and σ is an additional preference parameter. This utility function, suggested by Xiangkang Yin (2001a), is a generalization of the Cobb-Douglas function. One of the features of (1) is that a consumer will choose not to purchase good one when its price exceeds the individual's "reservation price" for the good. This feature is important when analyzing monopoly markets because it allows consumers not to purchase the monopolistically provided good. In fact, analyses of monopoly markets that use a Cobb-Douglas utility function are flawed because consumers will always purchase some of the monopolistically provided good regardless of its price. Note that $u_h(\cdot, \cdot)$ satisfies $u_{h1} > 0$ and $u_{h2} > 0$, and the matrix of second derivatives is negative semi-definite.

We can think of σ as indicating the consumer's benefit from good one; the lower σ is, the more the individual benefits from consuming good one. This is in contrast to ρ_h, which indicates the need a consumer h experiences for good one. To simplify the analysis, we choose to fix σ for all consumers. For example, in considering allergy medications, each dose may provide a similar benefit to each individual (same σ) in terms of reducing sinus congestion and other symptoms. However, the incidence and severity of these symptoms vary across the population (different ρ_hs). Some individuals do not need these medications at all; others desire small amounts of them, and yet others need larger quantities of them to achieve complete symptom relief.

Monopoly Equilibrium

A license is required to produce good one. A group of individuals, each denoted m for monopolist, share such a license. We assume they take on contiguous values of $\rho_m \in (0, c]$, where $c < 1$. Thus, c is the fraction of the population that owns shares in the monopoly, and shares equally any profit generated from the production and sale of the patented, branded pharmaceutical. Monopolists may use their own labor to produce good one and may hire any or all of the other individuals to produce good one, paying a wage rate w in units of good two per unit of labor. We assume the labor market is competitive, so that $w = a_2$ in equilibrium. The monopolists own all units of good one that are produced.[15] They may sell good one to nonmonopolists at price P (measured in units of good two per unit of good one). A monopolist's utility is given by (1) for $h = m$.

[15] Monopolists differ from nonmonopolists in two essential ways. First, each monopolist shares the license to produce good one and receives an equal share of any profits earned by the monopoly. Second, the fact that monopolists own

The other individuals (the nonmonopolists) behave competitively given the price P and the wage rate w. They choose consumption amounts and a labor allocation, dividing their labor between working for the monopolists to produce good one and producing good two on their own. In the continuum of consumers, they have ρ_h values that span the interval $(c, 1)$.

With three preference assumptions, it can be shown that a monopoly equilibrium (consisting of an equilibrium consumption, production and labor allocation; a price; and a wage) exists and is unique.[16]

Nonmonopolist Demand

Nonmonopolist h's demand for the drug is found through h's utility maximization subject to his or her budget constraint (total consumption value equals income: $Pc_{1h} + c_{2h} = a_2 l$). We define $\rho^*(P)$ to be the cutoff value of ρ_h for positive demand for good one at price P. Demand for good one is zero for individuals with $\rho_h \leq \rho^*(P)$ and positive for individuals with $\rho_h > \rho^*(P)$. The individual demands for good one and good two, as functions of the monopoly price P, are given by equations (2) and (3), respectively:

$$d_{1h}(P) = \begin{cases} \rho_h(a_2 l + P\sigma)/P - \sigma & \text{for } \rho_h > \rho^*(P) \\ 0 & \text{for } \rho_h \leq \rho^*(P), \end{cases} \tag{2}$$

and

$$d_{2h}(P) = \begin{cases} (1 - \rho_h)(a_2 l + P\sigma) & \text{for } \rho_h > \rho^*(P) \\ a_2 l & \text{for } \rho_h \leq \rho^*(P). \end{cases} \tag{3}$$

An expression for $\rho^*(P)$ is derived from the first row of equation (2):

$$\rho^*(P) = \frac{P\sigma}{a_2 l + P\sigma}. \tag{4}$$

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the units of good one they produce means they effectively are able to purchase good one at the marginal production cost. While they do not actually purchase the product, they incur either the direct cost of paying wages for good one production or, if they choose to produce good one themselves, the implicit cost of foregone units of good two. See Yin (2001b) for a model of shareholder price discounts, in which firm owners can purchase products at below-market prices. Since real-world owners of companies are generally unable to purchase products at cost, we chose to assign the monopolists the lowest values of ρ_m, where they are least likely to want to purchase good one. The assumption that monopolists can acquire good one at cost ensures that assigning them the lowest values of ρ will have no effect on the equivalent variation welfare analysis that follows.

[16] See Kelton and Wallace (1995). The first two of these assumptions are as follows. (1) There must exist a price, say P_H, above which there is no nonmonopolist demand for good one. (2) The total revenue function is strictly concave. A third assumption ensures that some trade will occur between the monopolists and nonmonopolists. As a group, the monopolists will choose positive amounts of both goods in equilibrium, as will the nonmonopolists. The equilibrium is unique in the sense of a unique price and unique sales of good one. We have nonsignificant multiplicity of equilibrium labor and output pairs.

Let $D_1(P)$ be aggregate nonmonopolist demand for good one at price P. We find $D_1(P)$ by integrating over those individuals with positive individual demands (those whose utility parameter exceeds $\rho^*(P)$), or over the set of all nonmonopolists, whichever is smaller. Hence,

$$D_1(P) = \int_{\rho=\max(\rho^*,c)}^{1} d_{1h}(P)d\rho = \int_{\rho=\max(\rho^*,c)}^{1} [\frac{\rho(a_2 l + P\sigma)}{P} - \sigma]d\rho. \tag{5}$$

When $\rho^*(P) \geq c$, the solution to this integral is[17]

$$D_1(P) = \frac{(a_2 l)^2}{2P(a_2 l + P\sigma)}. \tag{6}$$

Monopoly Sales, Price, and Profit

A monopolist m also maximizes his or her individual utility ((1) for $h = m$) subject to the budget constraint $(a_2/a_1)c_{1m} + c_{2m} = a_2 l + (\pi^*/c)$. That is, consumption value, with good one valued at marginal cost, cannot exceed monopolist income, which includes m's share of the profits from the sale of good one. To compute total monopoly profits, π^*, we first need to compute monopoly sales, q^*_{1M}, and the equilibrium price charged by the monopoly, P^*_M. These results are obtained by using equation (6) to determine marginal revenue and setting this equal to marginal cost, where $MC = a_2/a_1$. The approach is as follows:

Letting $D_1^{-1}(q)$ be the price at which nonmonopolists demand in total the quantity q of good one, we rewrite equation (6) as

$$q = \frac{a_2^2 l^2}{2D_1^{-1}(q)(a_2 l + D_1^{-1}(q)\sigma)}.$$

Solving for $D_1^{-1}(q)$ gives

$$D_1^{-1}(q) = \frac{a_2 l(\sqrt{q^2 + 2\sigma q} - q)}{2\sigma q}. \tag{7}$$

Then $TR(q) = qD_1^{-1}(q)$ is the total revenue from selling q units of good one.

Defining $MR(q)$ to be $\frac{\partial TR}{\partial q}$, we get

$$MR(q) = a_2 l\Big(\frac{q + \sigma - \sqrt{q^2 + 2\sigma q}}{2\sigma\sqrt{q^2 + 2\sigma q}}\Big).$$

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[17] To simplify the analysis we consider only the case of $\rho^*(P) \geq c$. This assumption has no qualitative effects on our results.

Setting $MR(q) = MC(q)$, where $MC(q) = a_2/a_1$, and solving for the optimal sales of the monopoly, q^*_{1M}, gives

$$q^*_{1M} = -\sigma + \frac{\sqrt{4\sigma^4 + 8a_1 l\sigma^3 + 5a_1^2 l^2\sigma^2 + a_1^3 l^3\sigma}}{2(a_1 l + \sigma)}. \tag{8}$$

Combining equations (7) and (8) and defining the equilibrium monopoly price, P^*_M, to be $D_1^{-1}(q^*_{1M})$, we find that

$$P^*_M = \frac{a_2 l}{2\sigma}\sqrt{\frac{\sqrt{4\sigma^2(a_1 l + \sigma) + \sigma a_1^2 l^2} + 2\sigma\sqrt{\sigma + a_1 l}}{\sqrt{4\sigma^2(a_1 l + \sigma) + \sigma a_1^2 l^2} - 2\sigma\sqrt{\sigma + a_1 l}}} - \frac{a_2 l}{2\sigma}. \tag{9}$$

It can be shown that the monopoly price exceeds the competitive equilibrium price (a_2/a_1) for all parameter values.[18]

The monopolists' total profits in equilibrium are

$$\pi^* = q^*_{1M}(P^*_M - \frac{a_2}{a_1}).$$

This profit is divided equally among the owners of the monopoly.

Monopoly Output and Employment

Whereas q^*_{1M} is the monopolists' profit-maximizing sales, total equilibrium production of good one, Q^*_1, is q^*_{1M} plus the monopolists' consumption of good one. In other words, production satisfies total demand for good one by both nonmonopolists and monopolist license holders. Subtracting the monopolists' own production of good one (good one produced with their own labor), enough nonmonopolist labor is hired to produce the remainder of Q^*_1.

Monopolist Consumption

A monopolist's utility maximization leads to the preferred consumption pair (c^*_{1m}, c^*_{2m}):

$$c^*_{1m} = \begin{cases} \rho_m(a_1 l + \frac{a_1\pi^*}{a_2 c} + \sigma) - \sigma & \text{for } \rho_m > \rho^*_m \\ 0 & \text{for } \rho_m \leq \rho^*_m \end{cases}$$

[18] In pharmaceutical markets, the markup over marginal cost, $P^*_M - (a_2/a_1)$, can be quite substantial. For example, when AZT, an antiretroviral medication, was first marketed by Burroughs Wellcome (now part of GlaxoSmithKline) in 1987, the drug was sold to wholesalers at a price of \$188 per hundred 100-mg capsules. It was estimated that the marginal cost of producing a single capsule was between 30 and 50 cents, implying a markup over cost of at least 276 percent. (See Kerin and Peterson, 1998.)

and

$$c^*_{2m} = \begin{cases} (1-\rho_m)(a_2 l + \frac{\pi^*}{c} + \frac{a_2\sigma}{a_1}) & \text{for } \rho_m > \rho^*_m \\ a_2 l + \pi^*/c & \text{for } \rho_m \leq \rho^*_m, \end{cases}$$

where ρ^*_m is the cutoff ρ_m value for positive demand for good one. Monopolists whose ρ_m value exceeds ρ^*_m consume a positive amount of good one, while those for whom $\rho_m \leq \rho^*_m$ consume none. Specifically,

$$\rho^*_m = \frac{a_2\sigma}{a_2\sigma + a_1 a_2 l + a_1(\pi^*/c)}. \tag{10}$$

Social Welfare Under Monopoly

Aggregate utility under monopoly is computed separately for nonmonopolists and monopolists. First, for nonmonopolists, combining equations (1), (2) and (3) gives nonmonopolist h's utility as a function of price:

$$u_h(d_{1h}(P), d_{2h}(P)) = \begin{cases} [\rho_h(a_2 l + P\sigma)/P]^{\rho_h}[(1-\rho_h)(a_2 l + P\sigma)]^{(1-\rho_h)} & \text{for } \rho_h > \rho^*(P) \\ \sigma^{\rho_h}(a_2 l)^{(1-\rho_h)} & \text{for } \rho_h \leq \rho^*(P), \end{cases}$$

where $\rho^*(P)$ is as previously defined. We calculate aggregate utility for nonmonopolists, W_{M1}, by integrating over all such individuals in the economy, remembering that nonmonopolists with sufficiently low values of ρ_h consume only good two. That is,

$$W_{M1}(P) = (a_2 l)\int_c^{\max(\rho^*(P),c)} \Big(\frac{\sigma}{a_2 l}\Big)^{\rho} d\rho + (a_2 l + P\sigma)\int_{\max(\rho^*(P),c)}^{1} P^{-\rho}\rho^{\rho}(1-\rho)^{(1-\rho)} d\rho. \tag{11}$$

The first integral gives the utility of nonmonopolists who do not consume good one, and the second gives the utility of those who do.[19]

For monopolists, we similarly integrate over the individual utilities. The utility of an individual monopolist m is

$$u_m(c^*_{1m}, c^*_{2m}) = \begin{cases} (a_2 l + \frac{\pi^*}{c} + \frac{a_2}{a_1}\sigma)\rho_m^{\rho_m}(1-\rho_m)^{(1-\rho_m)}(\frac{a_2}{a_1})^{-\rho_m} & \text{for } \rho_m > \rho^*_m \\ (a_2 l + \frac{\pi^*}{c})(\frac{\sigma}{a_2 l + (\pi^*/c)})^{\rho_m} & \text{for } \rho_m \leq \rho^*_m. \end{cases}$$

Monopolists whose utility parameter exceeds ρ^*_m consume a positive amount of good one, whereas those for whom $\rho_m \leq \rho^*_m$ consume none. The monopolists' aggregate utility is

$$W_{M2} = (a_2 l + \frac{\pi^*}{c})\int_0^{\min(\rho^*_m,c)} \Big(\frac{\sigma}{a_2 l + (\pi^*/c)}\Big)^{\rho} d\rho$$

[19]Solving the first of these integrals is straightforward. The lack of an analytical solution to the second integral forces us to resort to numerical techniques in the welfare analysis that follows. A similar problem exists for the second integral in equation (12).

$$+(a_2 l + \frac{\pi^*}{c} + \frac{a_2\sigma}{a_1}) \int_{\min(\rho_m^*, c)}^{c} \rho^\rho (1-\rho)^{(1-\rho)} \Big(\frac{a_2}{a_1}\Big)^{-\rho} d\rho. \qquad (12)$$

Social welfare under monopoly, W_M, is the sum of equations (11) and (12), i.e., $W_M = W_{M1} + W_{M2}$.

We also compute a measure of equivalent variation in income for each individual as an alternative approach to deriving social welfare. Using the utility an individual receives in the unrestricted monopoly regime as a benchmark, we compute the percentage change in income required for the individual to attain the same utility as he or she would obtain under the different policy proposals. Let y_h represent individual h's income in the unregulated monopoly regime, and let $v_h(y_h)$ be the utility h obtains with that income.[20] Then, let $v_{UI,h}$ be the utility individual h obtains under the universal insurance regime (for example). By computing a value for γ_h in equation (13) for each individual h, we determine how much better or worse off each individual is as a result of the universal insurance program:

$$v_h(y_h(1+\gamma_h)) = v_{UI,h}. \qquad (13)$$

The average of all individual equivalent variation values will be our aggregate measure of the benefit of adopting a universal insurance program. We compute a similar measure for the price ceiling regime.

3. A Price Ceiling

Although there currently is no explicit price cap on pharmaceuticals sold in the United States, both public and private payers have methods of cost containment that are meant either to bring down a drug's price or to reduce its utilization. All state Medicaid programs include a pharmaceutical benefit and have some cost-containment measures in place. Since the Omnibus Reconciliation Act of 1990, states may participate in the federal drug rebate program, in which pharmaceutical companies give rebates to Medicaid for using their drug. States are allowed to exclude certain drugs, such as cosmetic, hair-loss, weight-control and fertility drugs, from coverage. They may also adopt prior-authorization requirements to limit the use of more expensive drugs in a therapeutic class. All states require or encourage the use of generic drugs when possible, though a recent study by Fischer and Avorn (2003) concludes there is the potential for an additional $450 million in annual savings from greater use of generics across state Medicaid programs.

[20]For nonmonopolists, $y_h = a_2 l$, while, for monopolists, $y_h = a_2 l + (\pi^*/c)$.

Private-sector managed-care organizations and pharmaceutical-benefit management companies have an interest in keeping pharmaceutical costs down, although cost containment is not their only mission.[21] Their ability to use a formulary allows them to exclude the most expensive drugs in a therapeutic class. The prescription drug plans under the 2003 Medicare Reform Act will also be allowed to have a formulary in which inclusion of all drugs in a therapeutic class is not required.

We approximate price-reducing cost-containment strategies with a simple price ceiling on prescription drugs.[22] Of course the model is also directly relevant to any explicit form of price control, as exists today in most countries besides the United States. To be effective the price ceiling must be below the monopoly price, P_M^*. It must be above the marginal cost of production (a_2/a_1) in order for the monopoly to be viable. Let $\bar{P}$ denote the ceiling price.

$\bar{P}$ is the monopoly's marginal revenue. Since $MR > MC$ for all q, the monopoly produces as much output as nonmonopolists are willing to purchase at price $\bar{P}$. Using equation (6) to solve for the equilibrium quantity under a price ceiling, q^*_{ceil}, gives

$$q^*_{ceil} = \frac{a_2^2 l^2}{2\bar{P}a_2 l + 2\bar{P}^2\sigma}.$$

The monopoly's profits are

$$\pi^*_{ceil} = q^*_{ceil}(\bar{P} - \frac{a_2}{a_1}).$$

We compute individual utilities and social welfare using the previously derived equations evaluated at the ceiling price level $\bar{P}$. New cut-off ρ values, respectively denoted ρ^*_{ceil} and ρ^*_{mceil} for nonmonopolists and monopolists, differ from those obtained under unrestricted monopoly. For example, substituting $\bar{P}$ into equation (4) gives

$$\rho^*_{ceil} = \frac{\bar{P}\sigma}{a_2 l + \bar{P}\sigma}.$$

Similarly, equations (1), (2) and (3) allow us to write nonmonopolist h's utility:

$$u_h(d_{1h}(\bar{P}), d_{2h}(\bar{P})) = \begin{cases} [\rho_h(a_2 l + \bar{P}\sigma)/\bar{P}]^{\rho_h}[(1-\rho_h)(a_2 l + \bar{P}\sigma)]^{(1-\rho_h)} & \text{for } \rho_h > \rho^*_{ceil} \\ \sigma^{\rho_h}(a_2 l)^{(1-\rho_h)} & \text{for } \rho_h \leq \rho^*_{ceil}. \end{cases}$$

We again calculate social welfare by integrating over all individuals in the economy. First, for the nonmonopolists,

$$W_{Ceil1}(\bar{P}) = (a_2 l)\int_c^{\max(\rho^*_{ceil},c)} \Big(\frac{\sigma}{a_2 l}\Big)^{\rho} d\rho + (a_2 l + \bar{P}\sigma)\int_{\max(\rho^*_{ceil},c)}^1 \bar{P}^{-\rho}\rho^{\rho}(1-\rho)^{(1-\rho)} d\rho. \qquad (14)$$

[21] See Burton, *et al.* (2001) for a discussion of the ethics of managing pharmaceutical benefits.

[22] Our model does not consider utilization restrictions, as, for example, in prior-authorization programs. See Cook (1999) for a thorough discussion of various cost-containment measures.

The monopolists will purchase good one only if $\rho_m > \rho^*_{mceil}$ where ρ^*_{mceil} is as defined in equation (10) with $\pi^* = \pi^*_{ceil}$. Individual monopolist utilities are derived as in the previous section, though with $\pi^* = \pi^*_{ceil}$. Aggregate monopolist welfare is

$$W_{Ceil2} = (a_2 l + \frac{\pi^*}{c}) \int_0^{\min(\rho^*_{mceil}, c)} \Big(\frac{\sigma}{a_2 l + (\pi^*/c)}\Big)^{\rho} d\rho$$
$$+ (a_2 l + \frac{\pi^*}{c} + \frac{a_2 \sigma}{a_1}) \int_{\min(\rho^*_{mceil}, c)}^{c} \rho^{\rho} (1-\rho)^{(1-\rho)} \Big(\frac{a_2}{a_1}\Big)^{-\rho} d\rho. \tag{15}$$

Social welfare with a price ceiling set at $\bar{P}$ is the sum of equations (14) and (15), i.e., $W_{Ceil} = W_{Ceil1} + W_{Ceil2}$.

4. Universal Prescription Drug Insurance

Universal prescription drug insurance is an alternative approach to coping with the high and rising cost of drugs. In fact, the 2003 Medicare Reform Act takes us significantly "down the path" of universal prescription drug coverage. Between the people covered by Medicare and those covered by Medicaid, the public sector is responsible for drug benefits for a large sector of the population. Drug insurance permits sharing of the cost burden, so those experiencing the greatest need for a drug will not be forced to bear the cost alone. We model a system in which everyone's drug purchases are subsidized with revenue raised by an income tax imposed on all individuals. In spite of the fact that our model is simple relative to Medicaid programs or the new Medicare drug benefit program, it effectively reflects features such as coinsurance and protection for high-drug-use individuals. However, we do not include features such as benefit caps, deductibles, premiums and income-based eligibility requirements. We assume all individuals must participate in this program and that the labor income of all individuals is taxed at the same proportional rate in order to finance the program.

Purchases of the pharmaceutical are subsidized at rate δ per unit, leaving a coinsurance payment of $(1-\delta)$ per unit required to purchase good one. To finance the program, each individual is required to pay a portion t of his or her labor income in taxes. No capital income tax is imposed on the profits earned by monopolists.

The government is assumed to run a balanced budget with regard to this program. That is,

$$a_2 l t = \delta P_{UI} q_{UI}, \tag{16}$$

where q_{UI} is the total amount of good one purchased by nonmonopolists and P_{UI} is the price charged by the monopoly under universal insurance.

The budget constraint for nonmonopolist h becomes

$$P_{UI}(1-\delta)c_{1h} + c_{2h} \leq a_2 l(1-t). \tag{17}$$

That is, the value of expenditures on consumption of good two and the unsubsidized portion of good one cannot exceed after-tax income. Maximizing an individual's utility (1) subject to (17) we determine individual nonmonopolist demands for good one and good two. Then integrating over all nonmonopolists gives the following aggregate nonmonopolist demand for good one:

$$D_1(P_{UI}) = \frac{a_2^2 l^2 (1-t)^2}{2P_{UI}(1-\delta)\Big(a_2 l(1-t) + P_{UI}\sigma(1-\delta)\Big)}. \tag{18}$$

Set $q_{UI} = D_1(P_{UI})$ and solve for P_{UI}, the price the monopoly charges for good one:

$$P_{UI}(q_{UI}) \equiv D^{-1}(q_{UI}) = \frac{a_2 l(1-t)}{2\sigma(1-\delta)}\Big[\frac{\sqrt{q_{UI}^2 + 2q_{UI}\sigma}}{q_{UI}} - 1\Big]. \tag{19}$$

We next follow the same process as that used for the unrestricted monopoly model:

- Compute total revenue, TR:

$$TR(q_{UI}) = P_{UI} * q_{UI} = \frac{a_2 l(1-t)}{2\sigma(1-\delta)}[\sqrt{q_{UI}^2 + 2q_{UI}\sigma} - q_{UI}]. \tag{20}$$

- Determine $MR = \frac{\partial TR}{\partial q_{UI}}$, set $MR = MC$ $(= \frac{a_2}{a_1})$, and solve for q_{UI}^*, the equilibrium amount of good one purchased by nonmonopolists:

$$q_{UI}^* = \sigma\Big[\frac{x+1}{\sqrt{x(x+2)}} - 1\Big] \tag{21}$$

  where $x = \frac{2\sigma(1-\delta)}{a_1 l(1-t)}$. Substitute (21) into (19) to determine the equilibrium market price, P_{UI}^*.

- Find equilibrium profits, $\pi_{UI}^* = q_{UI}^*(P_{UI}^* - \frac{a_2}{a_1})$.

Nonmonopolist h's utility as a function of the price P_{UI} and of the policy parameters t and δ is

$$u_h(d_{1h}(P_{UI}), d_{2h}(P_{UI}), t, \delta) = \begin{cases} [a_2 l(1-t) + P_{NM}\sigma]\rho_h^{\rho_h}(1-\rho_h)^{(1-\rho_h)}[P_{NM}]^{-\rho_h} & \text{for } \rho_h > \rho_{UI}^* \\ \sigma^{\rho_h}(a_2 l(1-t))^{(1-\rho_h)} & \text{for } \rho_h \leq \rho_{UI}^* \end{cases}$$

where

$$\rho_{UI}^{*} = \frac{\sigma P_{UI}(1-\delta)}{a_2 l(1-t) + \sigma P_{UI}(1-\delta)}$$

and $P_{NM} = P_{UI}(1-\delta)$ is the effective price paid by nonmonopolists.

Welfare for the nonmonopolists is found by integrating the utilities of the nonmonopolists:

$$W_{UI1}(P_{UI}, \delta, t) = (a_2 l(1-t)) \int_{c}^{\max(\rho_{UI}^{*},c)} \Big(\frac{\sigma}{a_2 l(1-t)}\Big)^{\rho} d\rho$$
$$+(a_2 l(1-t) + P_{UI}(1-\delta)\sigma) \int_{\max(\rho_{UI}^{*},c)}^{1} [P_{UI}(1-\delta)]^{-\rho} \rho^{\rho}(1-\rho)^{(1-\rho)} d\rho. \tag{22}$$

The budget constraint facing monopolist m is

$$\frac{a_2}{a_1} c_{1m} + c_{2m} = a_2 l(1-t) + \frac{\pi_{UI}^{*}}{c}. \tag{23}$$

Maximizing an individual monopolist's utility subject to (23) gives the monopolist's optimal consumption amounts. Utility at these optimal consumption amounts is integrated over all monopolists. Total monopolist welfare is as follows:

$$W_{UI2} = (a_2 l(1-t) + \frac{\pi_{UI}^{*}}{c}) \int_{0}^{\min(\rho_{UIm}^{*},c)} \Big(\frac{\sigma}{a_2 l(1-t) + (\pi_{UI}^{*}/c)}\Big)^{\rho_m} d\rho_m$$
$$+(a_2 l(1-t) + \frac{\pi_{UI}^{*}}{c} + \frac{a_2\sigma}{a_1}) \int_{\min(\rho_{UIm}^{*},c)}^{c} \rho_m^{\rho_m}(1-\rho_m)^{(1-\rho_m)} \Big(\frac{a_2}{a_1}\Big)^{-\rho_m} d\rho_m \tag{24}$$

where

$$\rho_{UIm}^{*} = \frac{a_2\sigma}{a_2\sigma + a_1 a_2 l(1-t) + a_1(\pi_{UI}^{*}/c)}. \tag{25}$$

Social welfare under universal insurance will be the sum of equations (22) and (24), i.e., $W_{UI} = W_{UI1} + W_{UI2}$.

In equilibrium, we can use the fact that the government must run a balanced budget to rewrite its budget constraint (equation (16)) as

$$t = \frac{\delta P_{UI} q_{UI}}{a_2 l}. \tag{26}$$

This allows us to eliminate t from the above equations and to express the results solely in terms of δ. To demonstrate the validity of this approach we present the following lemma.

Lemma 1: *There exists a unique proportional tax rate t that balances the federal budget for each subsidy rate δ.* See the Appendix for a proof.

5. Welfare and Distributional Analysis

In this section we compute equilibria for the unrestricted monopoly, monopoly subject to a price ceiling and universal drug coverage; we compare the equilibria. The difficulty in obtaining a closed-form solution to several of the social welfare integrals makes analytical comparisons intractable; we conduct a numerical analysis instead.[23]

We recognize that different pharmaceutical products are consumed at different rates in the population and therefore examine two cases in detail. The first presumes the pharmaceutical is consumed by a relatively small portion of the population (e.g., 10 percent) when sold by an unrestricted monopolist. The second presumes the pharmaceutical is consumed by a much larger portion of the population (50 percent). (The utilization rate, as explained below, is directly related to the model's parameter σ.) Results for the two cases are qualitatively similar.

It is important to note that our objective cannot be to find a policy that is Pareto superior to an unregulated monopoly. This is because any policy that seeks to reduce the burden of pharmaceutical expenditures on purchasers necessarily shifts some of those expenses to other individuals without giving them any compensating benefit (other than perhaps the warm glow that comes from knowing other people's pharmaceutical expenses are not too onerous). Thus the best we can hope for is to improve overall social welfare.

Because the monopolists in our model obtain good one at cost in all three policy regimes (unrestricted monopoly, price ceiling, and universal insurance), our welfare-gain estimates are conservative. Under both policy classes, nonmonopolist buyers of good one experience welfare gains because of the decreased price of purchasing good one. Monopolists experience an income effect when their profits change but, because of the assumption that they can buy good one at cost, do not experience a welfare gain due to a change in the price of good one. The welfare gains reported in the following sections would be larger (and losses smaller) were we to relax this assumption.

[23]To ensure our results are robust to various parameter combinations, we assess the comparative statics of the model and conduct a comprehensive sensitivity study. Complete results are reported in Kelton and Rebelein (2005), and are largely as expected. For example, the monopoly price, P_M^*, decreases as good-one productivity, a_1, increases, while monopoly sales and profits increase as a_1 increases. All three quantities increase when the labor resource, l, increases. The welfare measures are relatively insensitive to changes in parameter values in the range of values employed for this study.

Calibration

To determine reasonable parameter values for l, a_1, a_2 and c, we calibrate our model to observations of the United States economy. According to the Bureau of Labor Statistics (BLS), there were 2,943.6 million hours worked per week in July 2003. The BLS reported total employment of 129,870,000 people that same month, resulting in an average of 22.67 hours worked per person per week. Extrapolating over an entire year gives an average of $l = 1182$ hours worked per person per year.

Values for a_1 and a_2 are derived from United States Census Bureau manufacturing data. 1997 data for Pharmaceutical Preparation Manufacturing (NAICS code 325412) indicate total employment of 115,781, with 62,741 production workers, and an average of 2020 hours worked per year by the latter.[24] Total value added by manufacture for the industry was $48,323.5 million in 1997, giving an average value added per hour worked of $206.6 in that year. Adjusting for changes in the producer price index gives a 2003 value of $273.1 for a_1. Similarly, we use Census Bureau data for All Manufacturing Establishments to determine a value for a_2.[25] Total employment of 16,805,127, with production workers working an average of 2004 hours per year (24.18 billion hours divided by 12.07 million production workers), generated manufacturing value added of $1,825,688 million. Average value added per hour worked was $54.2 in 1997. Adjusting for changes in the producer price index gives a 2003 value of $71.6 for a_2. Our calibrated a_2/a_1 ratio is 0.262. It seems as though "productivity" in pharmaceutical manufacturing, according to these simple statistics, is approximately four times as high as that in manufacturing as a whole.

To estimate the fraction of the population sharing the monopoly license (c), we find the portion of total market capitalization accounted for by the pharmaceutical industry. Rather than add up market capitalization for *all* pharmaceutical-producing firms, we determine market capitalization for five of the largest firms (Merck, Bristol Myers Squibb, Pfizer, Abbott and Eli Lilly) and divide by their market share of the pharmaceutical market (roughly 30 percent in 2002).[26] Dividing the result by total market capitalization for all firms (roughly $15 trillion in 2003 according to the New York Stock Exchange website) gives a pharmaceutical industry share of approximately 13 percent.

The final parameter, σ, indicating the benefit obtained from the pharmaceutical, is chosen to reflect particular consumption levels by the population. We examine two distinct cases: a high

[24] See the U.S. Census Bureau (1999), Table 2, "Industry Statistics for Selected States."

[25] See the U.S. Census Bureau (2001), Table 1-1a, "Statistics for All Manufacturing Establishments: 1997 and Earlier Years."

[26] See Gale (2005), which retrieved data from the *Encyclopedia of American Industries*.

value of σ corresponds to a low benefit across the population and to relatively low consumption; a low value of σ corresponds to a higher benefit across the population and to higher consumption. We choose the first value of σ in order to produce a cut-off value for nonmonopolists of $\rho^*(P_M^*) = 0.90$ under the unrestricted monopoly. In other words, only individuals with ρ_h higher than 0.90 (10 percent of the population) consume some of the pharmaceutical under the unrestricted monopoly. A second value of σ is chosen to produce a cut-off value for nonmonopolists of $\rho^*(P_M^*) = 0.50$. This implies a 50 percent utilization rate for the pharmaceutical under the unrestricted monopoly. Table I summarizes these calibration values.

In Table II we show equilibrium price and sales under unrestricted monopoly using the calibrated parameter values from Table I. The equilibrium monopoly price, P_M^*, is 0.55 (measured in units of good two per unit of good one) in the case of high σ, twice marginal cost ($a_2/a_1 = 0.26$), and 0.79, three times marginal cost, in the case of low σ. Monopoly sales are 7,673 with high σ and 26,904 with low σ.

Social Welfare Effects of a Price Ceiling

Using the calibrated parameter values from Table I we illustrate the welfare effects of a price ceiling. We vary the price ceiling level over an interval bounded by the monopoly price at the high end and the competitive price (marginal cost) at the low end. Table III presents the results for a pharmaceutical with a 10-percent utilization rate (high σ). Table IV presents the results for a pharmaceutical with a 50-percent utilization rate (low σ). We see in Table III that social welfare rises the more restrictive the price ceiling. More specifically, the increase in nonmonopolists' welfare exceeds the decline in monopolists' welfare. The results shown in Table IV are qualitatively similar. In each case social welfare rises as the level of the price ceiling falls, that is, as it approaches the competitive price.[27]

The last column of these two tables gives the average percentage by which income under the unregulated monopoly would need to increase in order to give all individuals the same utility as they receive with the price ceiling. Again, the data suggest the cost to monopolists of the price ceiling is less than the benefit received by nonmonopolists. In addition, this difference increases as the price ceiling is set lower and lower.

[27]This result may not occur for all industries. For some parameter configurations tested total welfare peaks not at the competitive price level, but at approximately one third of the way from the competitive to the monopoly price.

Table I: Calibrated Parameter Values

l	a_1	a_2	c	σ (High)	σ (Low)
1182	273.1	71.6	0.13	1,370,000	107,500

Table II: Benchmark Equilibria

	High σ (10% Utilization)	Low σ (50% Utilization)
Monopoly Price	0.55	0.79
Monopoly Sales	7,673	26,904
ρ^*	0.90	0.50

Table III: Price Ceiling Example 1 (10 % Utilization)

$\bar{P}$ (units of good 2)	q^*_{ceil}	Nonmonopolist Welfare	Monopolist Welfare	Total Welfare	Equivalent Variation
0.554	7,673	452,758	15,750	468,508	0.0%
0.524	8,502	453,110	15,743	468,853	0.28%
0.495	9,473	453,519	15,719	469,238	0.59%
0.466	10,621	453,997	15,673	469,670	0.95%
0.437	11,991	454,565	15,595	470,160	1.35%
0.408	13,645	455,247	15,475	470,722	1.82%
0.379	15,667	456,078	15,295	471,373	2.35%
0.350	18,176	457,107	15,031	472,139	2.98%
0.320	21,341	458,405	14,647	473,052	3.72%
0.291	25,413	460,073	14,086	474,159	4.61%
0.262	30,778	462,269	13,257	475,526	5.68%

Table IV: Price Ceiling Example 2 (50 % Utilization)

$\bar{P}$ (units of good 2)	q^*_{ceil}	Nonmonopolist Welfare	Monopolist Welfare	Total Welfare	Equivalent Variation
0.787	26,904	96,848	24,178	121,026	0.0%
0.734	29,819	98,123	24,147	122,270	1.79%
0.682	33,260	99,619	24,039	123,658	3.86%
0.629	37,366	101,393	23,827	125,220	6.28%
0.577	42,331	103,525	23,469	126,994	9.13%
0.524	48,427	106,122	22,907	129,029	12.55%
0.472	56,050	109,339	22,055	131,394	16.72%
0.420	65,799	113,407	20,778	134,185	21.90%
0.367	78,618	118,681	18,855	137,536	28.49%
0.315	96,091	125,743	15,899	141,642	37.14%
0.262	121,080	135,618	11,175	146,793	48.99%

Distributional Effects of a Price Ceiling

Figure 1 illustrates how individuals fare under a price ceiling on a drug with a 10-percent utilization rate. The price ceiling is set such that the markup over cost ($P_M^* - a_2/a_1$ in our model) is reduced by 50 percent from its level under unregulated monopoly. Utility differences and equivalent income variations are measured relative to the benchmark of unregulated monopoly. Most people are unaffected by the price ceiling since they do not consume the drug. The monopoly shareholders are worse off (suffering approximately a two-percent decrease in utility), while the drug consumers experience up to a four percent utility increase. Using equivalent variation, we see that high-ρ consumers can experience an effective increase in income of up to 35 percent when this price ceiling is in place.

Table V provides additional detail by dividing individuals into four groups. Monopolists are shareholders in the monopoly. "Non-Buyers" are nonmonopolists who choose not to purchase the pharmaceutical under either the unregulated monopoly or under the price-ceiling regime. "New Buyers" are nonmonopolists who choose not to purchase the pharmaceutical under the unregulated monopoly, but do purchase some when the price ceiling is imposed. "Always Buyers" are nonmonopolists who purchase the pharmaceutical under both regimes. The "Total" for each column is the average of the different equivalent variation values weighted by the fraction of the population in each group.

For a drug utilized by 50 percent of the population, monopolists experience the equivalent of a 1.0 percent income decrease when their markup is reduced 25 percent. They experience the equivalent of a 5.6 percent income decrease when their markup is reduced 50 percent. When the drug is used by a smaller proportion of the population (10 percent), the welfare losses are smaller. In each of the four scenarios in Table V, New Buyers and Always Buyers benefit from the price ceiling. Indeed, Always Buyers experience over a 20 percent effective increase in income when the markup is reduced 50 percent by the price ceiling.

It is interesting to note that the Total welfare improvement is larger the more restrictive is the price ceiling. Obviously a price ceiling could not be set so low as to prevent a firm from being able to recoup its R & D costs. However, for pharmaceuticals utilized by a relatively small protion of the population, it appears likely a price ceiling could provide substantial benefits to pharmaceutical users at only a modest cost to producers.

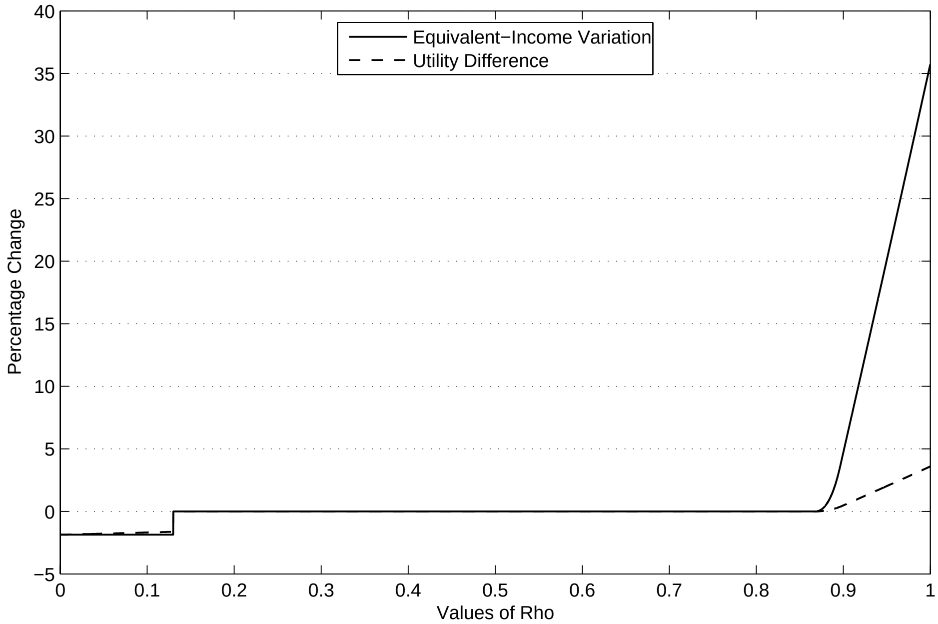

Figure 1: Comparison of Individual Utility Under Price Ceiling Versus Unrestricted Monopoly (50 % Markup Reduction and 10 % Utilization Rate)

Table V: Equivalent Variations for Price Ceiling Example

	Percent Income under Monopoly must Increase in order to achieve utility under Price Ceiling			
	50% Utilization		10% Utilization	
Group	25% Reduction[a]	50% Reduction	25% Reduction	50% Reduction
Monopolists	−1.0%	−5.6%	−0.3%	−1.9%
Non-Buyers	0.0%	0.0%	0.0%	0.0%
New Buyers	0.3%	1.3%	0.3%	1.4%
Always Buyers	10.3%	26.3%	8.0%	20.1%
Total	5.0%	12.6%	0.8%	1.8%

[a]The monopoly charges a price above the marginal cost of production (a_2/a_1). A 25% reduction indicates the price ceiling is set to eliminate 25 percent of this markup.

The Food and Drug Administration uses the term "orphan drug" to refer to a pharmaceutical that treats a rare disease, affecting fewer than 200,000 Americans. Pharmaceutical companies, concerned they will not be able to recoup their costs, generally choose not to undertake research and development of such drugs. The Orphan Drug Act, passed in 1983, encourages orphan drug development through tax incentives, grant funding and the granting of marketing exclusivity after product approval. If we set σ in our model to correspond to an orphan drug utilization rate of 0.1 percent and set the price ceiling to reduce 50 percent of the markup over cost we obtain the following results: the Always Buyers group experiences a welfare improvement equivalent to an income increase of 18.9 percent; the New Buyers experience a welfare improvement equivalent to an income increase of 1.6 percent; and the Monopolists experience a welfare decline equivalent to an income decrease of 0.01 percent. Non-Buyers are unaffected.

Social Welfare Effects of Universal Insurance

We next use the calibrated parameter values to determine the welfare effects of a simple universal prescription-drug insurance program. Table VI presents our results for the 10-percent utilization case (high σ). (Figure 2 presents some of these results graphically.) The first row of Table VI, with no subsidy or tax, corresponds to the unrestricted-monopoly benchmark from Table II. The first column of Table VI indicates the specific subsidy rate as a percentage of the pharmaceutical's market price. The second column indicates the proportional income tax rate required to balance the government's budget. For example, a 20 percent pharmaceutical subsidy could be financed with an income tax of 1.5 percent. The market price for a 20-percent subsidy rate is 0.560, compared to 0.554 for the benchmark. Monopoly sales are 11,132, higher than the benchmark sales of 7,673. Nonmonopolist welfare is lower than benchmark welfare because most nonmonopolists pay the tax and do not consume the pharmaceutical. Monopolist welfare increases relative to the benchmark, because of the larger profits they receive, and total welfare increases slightly. The final column shows that introducing a universal insurance program with a 20 percent subsidy would be equivalent to increasing all individuals' incomes by an average of 0.86 percent.[28]

Table VI and Figure 2 show that monopolist welfare increases as the subsidy rate, δ, and the corresponding tax rate, t, increase. Indeed, monopolist welfare should increase since the subsidy increases monopoly sales and profits. Nonmonopolist welfare, on the other hand, decreases as the

[28] By way of comparison, Moon and Storeygard (2002) also estimates the cost of various subsidy rates and concludes that a 23 percent subsidy rate would be appropriate to provide reasonable Medicare reform. This corresponds to a 2.0 percent income tax in Table VI. The 2003 Medicare Reform Act subsidizes most pharmaceutical expenditures at a 75-percent rate but includes various benefit caps and deductibles.

Table VI: Universal Insurance Example 1 (10 % Utilization)

Subsidy Rate	Tax Rate	P_{UI} (units of good 2)	q_{UI}	Nonmonopolist Welfare	Monopolist Welfare	Total Welfare	Equiv. Variation
0 %	0.0 %	0.554	7,673	452,758	15,750	468,508	0.0%
10 %	0.6 %	0.557	9,171	452,647	16,189	468,835	0.41%
20 %	1.5 %	0.560	11,132	452,386	16,763	469,149	0.86%
30 %	2.8 %	0.564	13,755	451,874	17,533	469,407	1.38%
40 %	4.7 %	0.570	17,353	450,933	18,594	469,527	2.00%
50 %	7.6 %	0.576	22,422	449,221	20,104	469,326	2.66%
60 %	12.4 %	0.585	29,781	446,044	22,331	468,375	3.14%
70 %	20.1 %	0.597	40,800	439,865	25,744	465,609	3.28%
80 %	33.5 %	0.612	57,787	426,852	31,188	458,039	1.92%
90 %	57.0 %	0.634	84,589	395,069	40,207	435,276	−4.84%

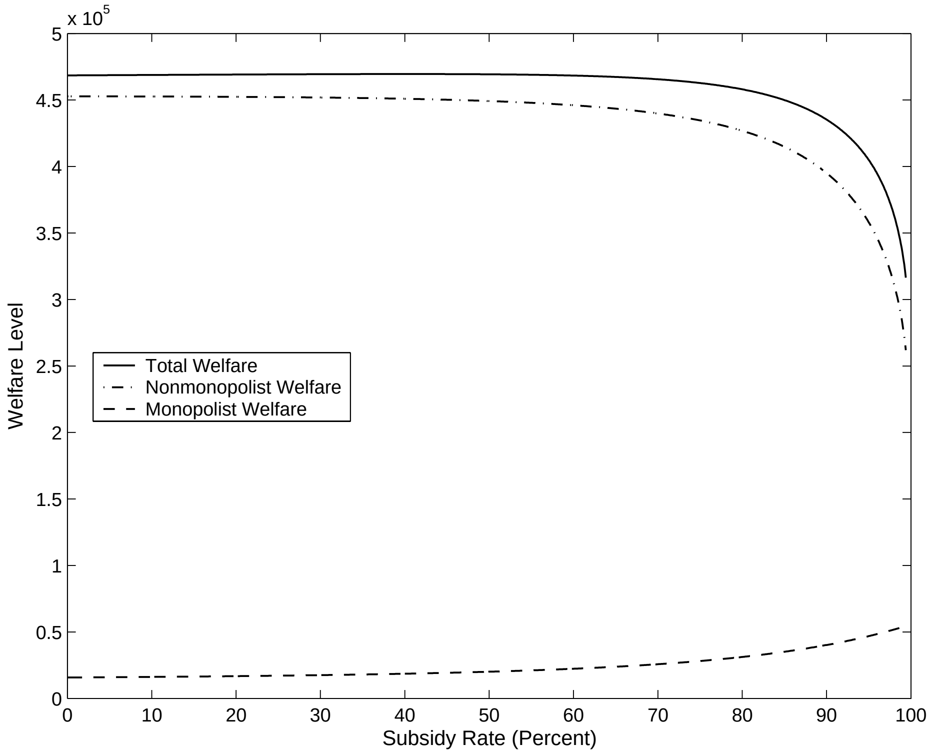

Figure 2: Welfare under Universal Insurance (10 % Utilization Rate)

subsidy rate increases. The subsidy encourages more individuals to purchase the pharmaceutical, but the majority still choose not to do so. The benefit of being able to purchase subsidized pharmaceuticals is clearly outweighed by the consequence of being taxed to pay for the subsidy. For subsidy rates below 40 percent, total welfare increases as the subsidy rate increases. Nonmonopolist welfare decreases less than monopolist welfare rises for subsidies in this range. At subsidy rates up to 50 percent, total welfare exceeds that of the unregulated monopoly. Note that the equivalent variation is positive up to a subsidy rate of 80 percent. Both the total welfare and equivalent variation measures show that the universal insurance program can improve social welfare beyond that obtained in the benchmark case.

Table VII and Figure 3 present results for a pharmaceutical with a 50-percent utilization rate (low σ). The results are qualitatively identical to those obtained in the high-σ case. While monopolist welfare increases consistently with an increase in the drug subsidy rate, nonmonopolist welfare falls.[29] Total welfare exceeds benchmark welfare at all subsidy rates. At subsidy rates up to 50 percent, the equivalent variation measure shows an increase in welfare relative to the benchmark.

Figure 4 illustrates the difference in equivalent variation values for different pharmaceutical utilization rates. The data here suggest greater welfare gains are available the less the pharmaceutical is consumed across the population. In addition, we see the welfare-maximizing subsidy rate can be different for pharmaceuticals with different utilization rates. A subsidy rate of 60–70 percent may maximize welfare for a product consumed by a relatively small portion of the population, but this rate could actually cause a welfare decline if applied to a pharmaceutical consumed by a large portion of the population. This suggests it may be necessary to classify pharmaceuticals as to the prevalence of their use before implementing this kind of universal insurance program.

A lingering concern about our welfare results may be the assumption that monopoly owners can purchase good one at cost. This concern arises since the lower price is one source of the higher utility received by monopolists. To investigate this concern, we repeat the preceding analysis assuming the monopoly owners face the (subsidized) market price for good one. There were no differences from the original results in the 10-percent utilization case – the low utilization rate means that, even at very high subsidy rates, monopoly owners will not choose to purchase good one.

[29] There is an increase in nonmonopolist welfare as the subsidy rate rises from zero to 5 percent, but, at subsidy rates above 5 percent, welfare declines.

Table VII: Universal Insurance Example 2 (50 % Utilization)

Subsidy Rate	Tax Rate	P_{UI} (units of good 2)	q_{UI}	Nonmonopolist Welfare	Monopolist Welfare	Total Welfare	Equiv. Variation
0 %	0 %	0.787	26,904	96,848	24,178	121,026	0.0%
10 %	2.8 %	0.802	29,318	96,871	25,445	122,317	0.48%
20 %	6.2 %	0.820	32,060	96,761	26,925	123,686	0.86%
30 %	10.5 %	0.839	35,189	96,453	28,668	125,121	1.03%
40 %	15.8 %	0.861	38,782	95,850	30,740	126,591	0.92%
50 %	22.5 %	0.886	42,934	94,797	33,233	128,030	0.32%
60 %	31.0 %	0.914	47,769	93,036	36,269	129,305	−1.05%
70 %	41.9 %	0.947	53,448	90,102	40,018	130,120	−3.71%
80 %	56.0 %	0.985	60,183	85,045	44,725	129,771	−8.70%
90 %	74.8 %	1.030	68,263	75,353	50,748	126,101	−18.6%

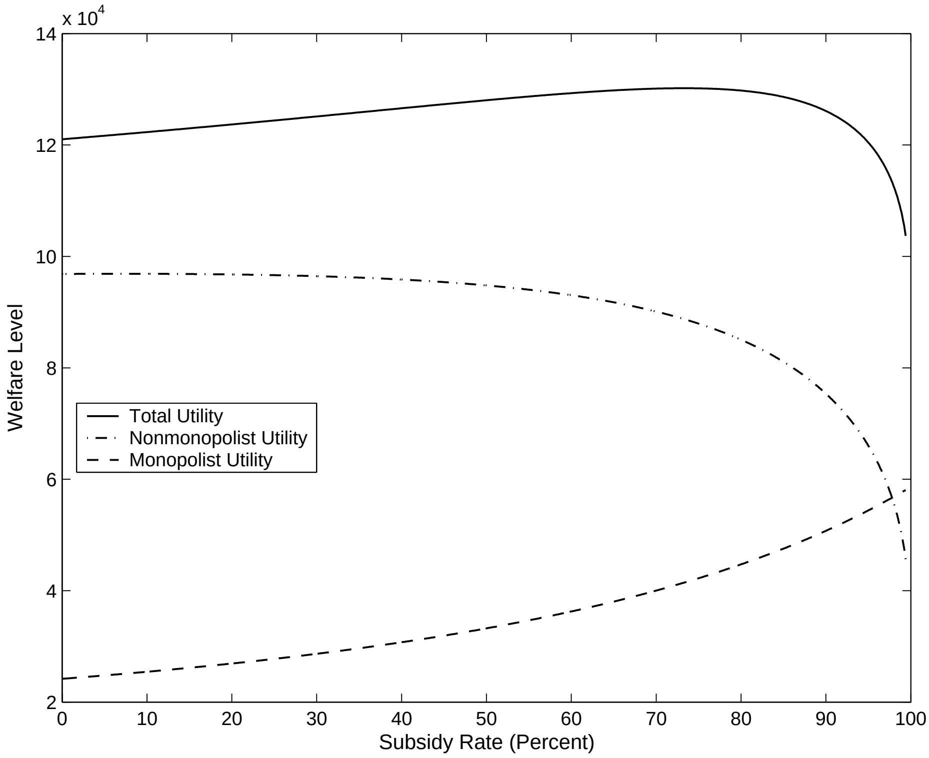

Figure 3: Welfare under Universal Insurance (50 % Utilization Rate)

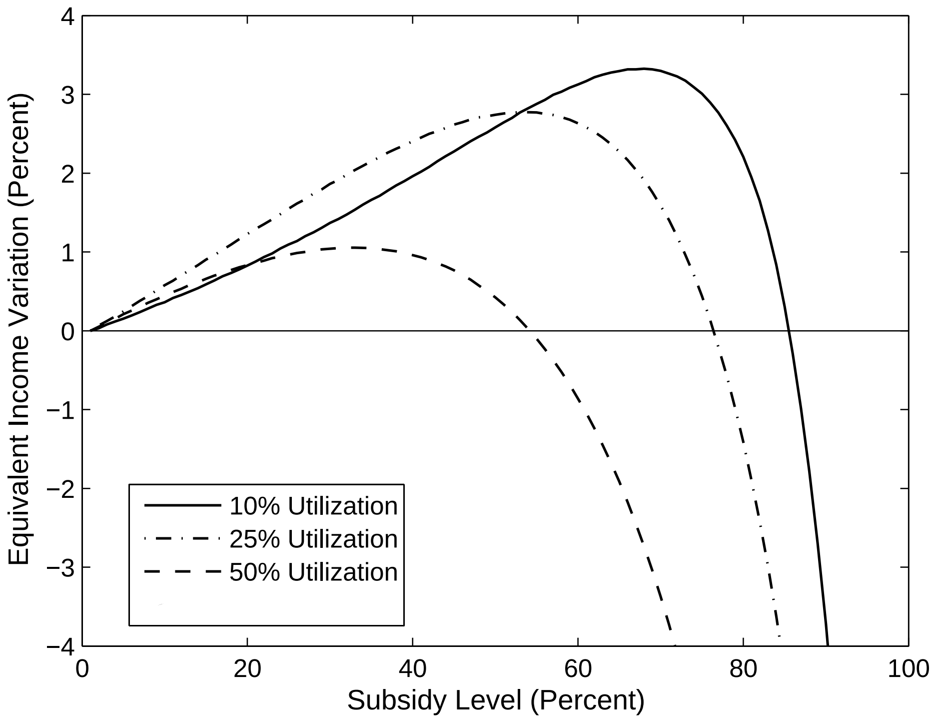

Figure 4: Equivalent Variations at Different Drug Utilization Rates

In the second case (50 percent utilization), monopoly owners purchase some of good one at subsidy rates in excess of 60 percent. Hence our welfare results differ at these high subsidy rates from those in Table VII. Table VIII presents the aggregate equivalent variation values assuming monopolists must pay the market price, P^*_M, under unregulated monopoly and pay the subsidized price, $P^*_{UI}(1-\delta)$, under universal insurance. For comparison purposes, the original equivalent variation values are repeated. The differences between the initial equivalent variation values and the new equivalent variation values are small and all values have the same signs.[30] Therefore, we conclude that the assumption that monopolists may buy good one at cost has little effect on the results of our analysis.

Distributional Effects of Universal Insurance

We next look more closely at the distributional effects of the universal insurance regime. We choose a specific subsidy level (δ =50%) and specific utilization rate of 10 percent and compute two measures of the benefits (or consequences) accruing to different individuals.[31] We first compare the utility individual h receives under the universal insurance regime with the utility he or she receives under the unrestricted monopoly regime. We find that two groups of individuals – monopolists and high-drug-need nonmonopolists – have higher utility under universal insurance. Other nonmonopolists do better under the unrestricted monopoly regime. The percentage difference in utility obtained by different individuals is shown graphically by the dashed line in Figure 5.

Using the equivalent variation approach we again find that monopolists benefit under universal insurance, as do the nonmonopolists who actually consume the pharmaceutical, while the majority of nonmonopolists are better off under unrestricted monopoly. For monopolists, changing to a universal insurance regime is similar to giving them a 30 percent increase in income (see the solid line in Figure 5). For the individuals with the greatest need for the pharmaceutical, changing to a universal insurance regime is similar to giving them a 50 to 75 percent increase in income. For nonmonopolists who do not consume the pharmaceutical, changing to a universal insurance regime is equivalent to taking away approximately seven percent of their income.

Table IX, like Table V above, provides additional detail for four groups. The effects are as expected: the higher the subsidy rate the better off are members of the Monopolists and Always

[30] As discussed earlier, the computed welfare losses are larger when monopolists are allowed to acquire good one at cost, supporting the idea that our welfare estimates in Tables III – VII are conservative.

[31] Other δ selections give results similar to those described below.

Table VIII: Universal Insurance at High Subsidy Rates when Monopolists Pay Market Price for Good One (50 % Utilization)

Subsidy Rate	Initial Equivalent Variation	New Equivalent Variation
60 %	−1.05 %	−1.05 %
70 %	−3.71 %	−3.68 %
80 %	−8.70 %	−8.46 %
90 %	−18.6 %	−17.4 %

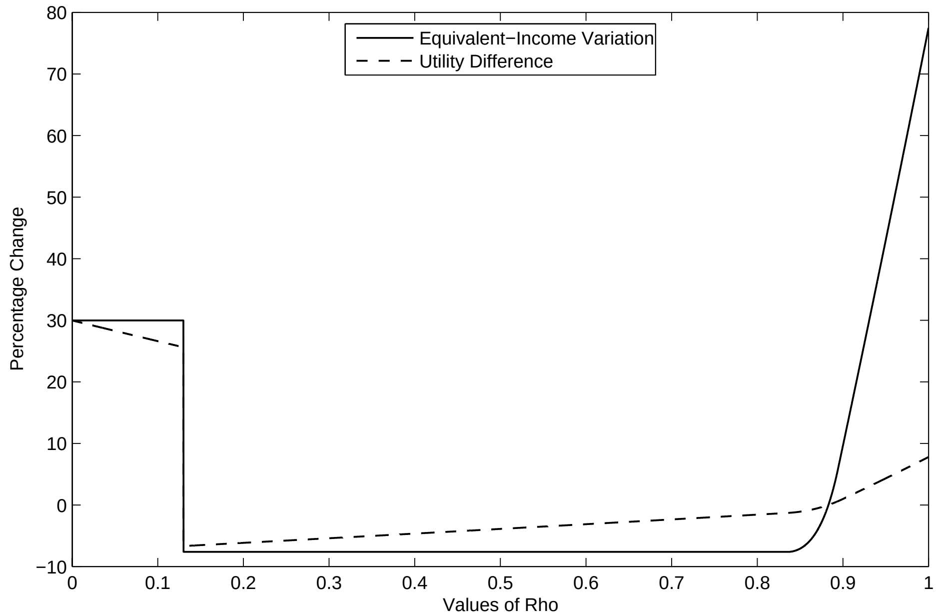

Figure 5: Comparison of Individual Utility Under Universal Insurance Versus Unrestricted Monopoly (50 % Subsidy Rate and 10 % Utilization Rate)

Buyers groups, while members of the other groups are made worse off because of the higher tax rate required. Also expected are the smaller gains for the Monopolists, and losses for the Non-Buyers and New Buyers, at the lower utilization rate. Surprising, however, is the greater benefit received by the Always Buyers group at the lower utilization rate. This is also reflected in the higher totals (shown in the last row of Table IX) for the lower utilization rate. These data suggest a universal insurance program for pharmaceutical products that first targets pharmaceuticals consumed by relatively small portions of the population would produce the greatest social welfare gain, while imposing the smallest burden on non-pharmaceutical consumers.

As was observed for a price ceiling, substantial welfare gains are possible for drugs with very low utilization rates with only a modest welfare cost. If we set σ in our model to correspond to an "orphan" drug utilization rate of 0.1 percent and set the subsidy rate at 50 percent we obtain the following results: the Always Buyers group experiences a welfare improvement equivalent to an income increase of 65 percent; the New Buyers experience a welfare improvement equivalent to an income increase of 7.4 percent; and the Monopolists experience a welfare improvement equivalent to an income increase of 0.5 percent. Only the Non-Buyers lose, with a welfare decline equivalent to an income decrease of 0.1 percent. This result is consistent with the trend (observed above) that subsidizing less-utilized drugs produces larger social welfare gains overall with fewer adverse distributional effects.

Political Economy Implications

A 2005 Standard and Poors report concludes that many pharmaceutical manufacturers earn profits in excess of 20 percent of their costs.[32] Earlier (fn. 9) we indicated that some individual pharmaceutical products recorded sales in excess of $2 billion in 2004 alone, suggesting profits approaching $400 million annually for a single patented pharmaceutical product. We are not suggesting all pharmaceutical products generate this much profit; however, there is almost certainly room for price reductions without choking off R & D. For example, a firm earning profits of $200 million per year will recoup its R & D costs in only four years (on average) with at least six years of effective patent coverage yet to come. Reducing pharmaceutical markups by 50 percent would still allow such a firm to recoup its R & D costs within the period of patent protection and also generate profits for its shareholders.

[32] See Standard and Poors, *Industry Survey*, July 21, 2005.

Table IX: Equivalent Variations Under Universal Insurance

	Percent Income under Monopoly must Increase in order to achieve utility under Universal Insurance			
	50% Utilization		10% Utilization	
Group	25% Subsidy	50% Subsidy	25% Subsidy	50% Subsidy
Monopolists	16.0%	40.5%	9.4%	29.9%
Non-Buyers	−8.2%	−22.5%	−2.1%	−7.6%
New Buyers	−8.1%	−21.8%	−1.1%	−2.9%
Always Buyers	3.9%	6.7%	14.8%	43.0%
Total	1.0%	0.3%	1.1%	2.6%

With respect to universal insurance, Figure 5 above illustrates the problem of implementing a universal insurance scheme through majority-rule voting. Roughly 25 percent of the individuals have positive equivalent variation values under the insurance plan, while the rest are worse off and would, as rational voters, not support the plan. As such, a simple one-person, one-vote, majority-rule voting system would reject such a program. In practice, however, not everybody votes. Elderly individuals are more likely to vote and more likely to be pharmaceitucal consumers. In contrast, young individuals are less likely to vote and less likely to be pharmaceutical consumers.[33] Conceivably a coalition of monopoly owners and elderly drug consumers could generate sufficient votes to overcome the apathy of the nonconsumers and pass a drug subsidy program. In fact, because the benefits accruing to monopoly owners and high drug users continue to increase as the subsidy rate increases, a coalition of these two groups may vote for a plan with a subsidy rate that is too high to be welfare-improving for the economy as a whole. Risk aversion may elicit additional support for a universal insurance program were everyone to have some small probability of needing a very expensive medication.[34]

Short of a successful popular vote, it would fall to the government to implement a social-welfare-enhancing price ceiling or universal insurance program for prescription drugs. Our results clearly suggest the government is correct to do this in the case of orphan drugs.

6. Conclusion

For the last decade, both the public and private sectors of the economy have been forced to respond to the high and rising cost of pharmaceuticals. Responses such as cost-containing formularies or insurance plans, that shift some of the cost burden away from high-need consumers, are arising rapidly. Practical, individualized solutions developed by hospitals, pharmacies, or third-party payers are emerging in a state of urgency. Our paper steps back from the immediacy of the problem in order to develop a framework for making comparisons of social-welfare implications across policy regimes.

[33]The U.S. Census Bureau estimates that 65.1 percent of individuals aged 65 to 74 voted in the 2002 elections while only 31.8 percent of individuals aged 25 to 34 turned out to vote. See Day and Holder (2004).

[34]Bednarek and Pecchenino (2002) offer an example of explicit modeling of uncertainty regarding the severity of an illness. In their overlapping generations model, an individual has different probabilities of contracting an illness of minor or major severity in their second (final) period of life.

Since partial-equilibrium models ignore the interactions between the drug market and markets for other goods, we work with a general-equilibrium monopoly model in order to gain a complete picture of the effects these policies may have. Our model clearly shows the interaction between the pharmaceutical market and the rest of the economy. Further, it accounts for both consumer and shareholder well-being by explicitly modeling the preferences of both groups. In the context of our general-equilibrium framework, we compare social welfare occurring under the current, patented-monopoly, system to that for two possible alternative policy regimes: a price ceiling on the monopolistically produced good and a simple form of universal insurance. We find significant potential for improvement under both policy regimes.

The pattern of gains resulting under a price ceiling is as expected: the lower the ceiling the greater the welfare redistribution from monopolists to nonmonopolist drug consumers. While the welfare gains experienced by drug consumers are substantial, the welfare losses incurred by monopolists are modest, leading to an overall welfare increase. The pattern of welfare gains and losses is also as expected with universal insurance: monopolists and drug consumers gain while non-drug consumers foot the bill. For lower subsidy (and tax) rates, gains to monopolists and high-need drug consumers exceed the welfare losses to other nonmonopolists, leading to an overall increase in social welfare. Both the price ceiling and universal insurance programs offer clear gains for high-need pharmaceutical consumers. The primary difference between the two programs is the effect each has on the welfare of monopolists.

Under both policy regimes, the welfare gains for drug consumers are particularly substantial relative to the losses incurred by others when the drug is consumed by only a small portion of the population. This result suggests these policies could be especially helpful in ensuring accessibility to so called "orphan" drugs. In particular, we find that subsidizing orphan drugs even at very high subsidy rates is welfare-improving, with little consequence for monopolists.

While the general-equilibrium model is able to mimic several features of real-world pharmaceutical markets and cost-containment and insurance proposals, future research should incorporate even more realism. Phenomena we would like to add include explicit modeling of the R & D process in the branded pharmaceutical sector; heterogeneity in the income profiles of individuals in the economy; the effects of pharmaceutical companies' advertising; individual uncertainty regarding a consumer's need for the pharmaceutical; and a market for a generic pharmaceutical product.

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Appendix

Proof of Lemma 1

The proof proceeds in two parts. We first show there exists at most one t for each δ that will balance the federal budget. We then show there exists at least one t for each δ.

1. To show there exists at most one t for a given δ, we show that government revenues are strictly increasing in t, while the cost of the subsidy is strictly decreasing in t. Thus, there exists at most one intersection of the government's revenue and cost curves for each subsidy rate δ.

   Since labor is inelastically supplied by all individuals, increases in t will not cause any reduction in labor effort, and tax revenues will be strictly increasing as t increases.

   To show total cost is strictly decreasing, we begin with equation (21) and differentiate q_{UI} with respect to t:

$$\frac{\partial q_{UI}}{\partial t} = \sigma\left(\frac{\sqrt{x(x+2)}\frac{\partial x}{\partial t} - (x+1)\frac{1}{2}(x(x+2))^{-\frac{1}{2}}(2x\frac{\partial x}{\partial t} + 2\frac{\partial x}{\partial t})}{x(x+2)}\right),$$

   which reduces to

$$\frac{\partial q_{UI}}{\partial t} = \sigma\frac{\partial x}{\partial t}\frac{-1}{(x(x+2))^{3/2}}.$$

   From the definition of x following equation (21),

$$\frac{\partial x}{\partial t} = \frac{2\sigma(1-\delta)}{a_1 l}\Big(\frac{1}{(1-t)^2}\Big) = \frac{x}{1-t}.$$

   Since all parameter values are positive, and t and δ are less than one, $\frac{\partial x}{\partial t}$ is positive, and, therefore, q_{UI} is strictly decreasing in t.

   Next we differentiate the total subsidy cost $\delta P_{UI}q_{UI}$, where $P_{UI}q_{UI}$ is given by equation (20), with respect to t:

$$\frac{\partial}{\partial t}(\delta P_{UI}q_{UI}) = \frac{\delta a_2 l}{2\sigma(1-\delta)}\Bigg[(1-t)\Big(\frac{1}{2}(q_{UI}^2 + 2q_{UI}\sigma)^{-1/2}(2q_{UI}\frac{\partial q_{UI}}{\partial t} + 2\sigma\frac{\partial q_{UI}}{\partial t}) - \frac{\partial q_{UI}}{\partial t}\Big) + [\sqrt{q_{UI}^2 + 2q_{UI}\sigma} - q_{UI}](-1)\Bigg]$$

$$= \frac{\delta a_2 l}{2\sigma(1-\delta)}\Bigg[(1-t)\frac{\partial q_{UI}}{\partial t}\Big((q_{UI}^2 + 2q_{UI}\sigma)^{-1/2}(q_{UI}+\sigma) - 1\Big) + \Big(q_{UI} - (q_{UI}^2 + 2q_{UI}\sigma)^{1/2}\Big)\Bigg].$$

The leading term is positive, as is $(1-t)$, and we showed above that $\frac{\partial q_{UI}}{\partial t} < 0$. The last term, $(q_{UI} - (q_{UI}^2 + 2q_{UI}\sigma)^{1/2})$, is clearly negative, so if

$$(q_{UI}^2 + 2q_{UI}\sigma)^{-1/2}(q_{UI} + \sigma) - 1 > 0,$$

we will have our desired result. We rewrite the left-hand side as

$$\frac{q_{UI} + \sigma}{\sqrt{(q_{UI} + \sigma)^2 - \sigma^2}} - 1$$

which is clearly greater than 0.

2. To show there exists at least one t for each $\delta \in (0, 1)$ we consider the values of the revenue and subsidy that result at the extremes of $t = 0.0$ and $t = 1.0$. Assume δ is fixed. When $t = 0$ the government raises no revenue; when $t = 1$ the government collects $a_2 l$. The subsidy cost when $t = 1$ will be zero since nonmonopolists have no disposable income. The subsidy cost when $t = 0$ is necessarily positive. This is because we assume the nonmonopolists purchase a positive amount of good one when the monopoly is unregulated (i.e., when $\delta = 0$). With $\delta > 0$ the price facing nonmonopolists declines so they purchase at least as much as they do when $\delta = 0$. Finally, since government revenue rises from zero on the interval $t \in [0, 1]$ and subsidy cost declines to zero on this interval, it must be that they intersect at some value of $t \in (0, 1)$.

Q.E.D.