Social Welfare Loss in Antidepressant and Antipsychotic Pharmaceutical Markets

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October 2005

Abstract

We study allocative inefficiency under monopoly using a two-good general-equilibrium monopoly production model. Individuals are heterogeneous with respect to preferences. We compare social welfare under monopoly with welfare under perfect competition. We then apply this model to the antidepressant and antipsychotic pharmaceutical markets. We find that, for nine specific drugs, annual social-welfare losses ranged from $63 million to $658 million in 2003. We estimate the true cost of introducing a new pharmaceutical product under the current patented monopoly system to be approximately $4.2 billion.

Key words: General equilibrium, Social welfare, Allocative efficiency, Monopoly versus competition, Pharmaceutical markets.

JEL Codes: D42, D61, I11, L12

*We are indebted to Neil Wallace for allowing us to use this model. We want to thank Jeff J. Guo for his collaboration on antidepressant and antipsychotic medications. We also want to thank Yeon-Koo Che for helpful suggestions. Any errors are the responsibility of the authors. Comments are welcome and may be directed to the authors at chris.kelton@uc.edu or rebelein@vassar.edu. Corresponding author: Robert P. Rebelein, Department of Economics, Vassar College, 124 Raymond Ave., #290, Poughkeepsie, NY 12604; email: rebelein@vassar.edu; phone: 845-437-7393; fax: 845-437-7576.

1 Introduction

To encourage new drug discovery and development, the government grants pharmaceutical companies patents for their innovations that allow them to obtain monopoly profits and charge monopoly prices for a period of time. 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. When the patent expires, companies producing generic equivalents begin to enter the market, and eventually the market for that generic compound starts to become competitive. Simultaneously, however, newer drugs replace older, less effective medicines. For example, the market for anti-ulcer gastric medications, 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 it (Guo, *et al.*, 2004).

As it turns out, the newer, more expensive patented medications are currently replacing the older medications faster than generic entry reduces the costs of older medications going off-patent.[1] Schondelmeyer (2000) reported that, because of the substitution of newer for older medicines, the proportion of generic drug utilization in Medicaid programs actually declined from 54 percent in 1995 to 51 percent in 1998. The resulting rise in the average price of drugs, coupled with rising drug utilization, has caused drug expenditures to rise precipitously over the last decade.[2] 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 further reduced by rebates given by pharmaceutical manufacturers. 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.[3]

With the stress on consumers and insurers caused by these high and rising drug costs, it becomes important for pharmaceutical economists and policy-makers to evaluate carefully the tradeoff between drug innovation and drug affordability. Indeed, a number of recent analyses describe research and development (R & D) in the pharmaceutical sector. According to the Pharmaceutical Research

and Manufacturers of America (2005), drug companies in the United States have nearly doubled their R & D investment every five years since 1980, from $2 billion in 1980 to $39 billion in 2004. Between 1990 and 2004, the Food and Drug Administration approved a total of 1,284 new drug applications (Food and Drug Administration, 2005). The R & D cost associated with bringing a new drug to market averages over $800 million (DiMasi, Hansen, and Grabowski, 2003). Moreover, the quality of new drugs has been increasing over time. Using the Medical Expenditure and Panel Survey data, Lichtenberg (2000) showed that the replacement of older drugs by newer, more expensive drugs not only reduced mortality and morbidity rates due to illness, but also reduced the total medical cost of treating the condition.

Besides the large R & D expense, there is an additional social cost associated with new-drug production and distribution. To achieve the benefits of new drug development, we tolerate allocative inefficiency (static social welfare loss) over the life of the drug company's patent. To our knowledge there has been no recent study that attempts to measure the social welfare loss caused by patented monopoly in the pharmaceutical industry. This paper fills that gap and does so by introducing a new model appropriate for such an analysis. To develop economically sound policy toward the pharmaceutical sector, the true cost of new drug provision (R & D plus allocative inefficiency) must be compared with the benefits of innovation.[4]

Most previous literature on the measurement of allocative inefficiency in a market starts with Figure 1, which depicts the deadweight loss (DWL) associated with a constant-marginal-, constant-average-cost monopoly. The DWL "triangle" represents the loss to the economy resulting from a market's being organized monopolistically as opposed to competitively. A large empirical literature dating from Harberger (1954) seeks to provide an estimate of aggregate DWL for the economy.[5] This triangle has motivated numerous empirical studies linking monopolistic market structure with higher prices (see Weiss, 1989, for a collection of industry studies of this type), establishing that lower allocative efficiency is associated with monopolistic markets.

[insert Figure 1 here]

Our paper measures allocative inefficiency for four selective serotonin reuptake inhibitor (SSRI) antidepressants and five atypical antipsychotic pharmaceuticals that were under patent in 2003.

In doing so, however, we do not use the partial-equilibrium approach that Figure 1 depicts. We adopt instead the general-equilibrium monopoly model of Kelton and Wallace (1995). The general-equilibrium model is superior in its ability to account for interactions between the monopolistic and nonmonopolistic sectors. In addition, the preferences of all individuals (whether monopoly shareholders or not) are explicitly modeled. Since partial-equilibrium analyses ignore interactions with other sectors of the economy they tend to give pessimistic estimates of allocative inefficiency. The general-equilibrium results take into account increased utility from consumption in the other sectors and, therefore, produce more accurate (smaller) estimates of the monopoly losses. Kelton and Rebelein (2005) uses a similar general-equilibrium framework to explore the welfare and distributional effects of public prescription-drug insurance and price-ceiling policies for the pharmaceutical sector.[6]

Insurance is not included in our analysis (Kelton and Rebelein, 2005, offers an example of a similar analysis that incorporates insurance) meaning we cannot speak to either the problem of moral hazard (leading to overconsumption of medications) or to the distributional impact of monopoly on individuals (after all, taxpayers, not necessarily high drug users, are paying for a lot of the medications). However, the model may be used for our purpose (obtaining a measurement of economy-wide allocative inefficiency) and can certainly be applied as well to other monopoly sectors of the economy in which insurance plays a less important role.

To our knowledge there exists only one other general-equilibrium analysis of pharmaceutical markets. Canton and Westerhout (1999) developed 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 nature of pharmaceutical innovators.[7]

The analysis proceeds as follows. Section 2 develops the two-good general-equilibrium monopoly production model. The monopoly equilibrium is described. Section 3 compares social welfare under monopoly to welfare under perfect competition. In Section 4, we calibrate the model to specific targets in the antidepressant and antipsychotic markets in the United States economy and estimate social welfare loss for nine patented drugs. Section 5 concludes.

2 The Model

This section describes the model used for our analysis, including the competitive and monopoly equilibria. It also presents some comparative statics for the model aggregates.

2.1 The Environment

The model is a two-good, general-equilibrium model in a production environment.[8] 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 $a_2 l_{2h}$.[9]

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.[10] We can think of σ as indicating (inversely) 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 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 attain complete symptom relief.

Committing ourselves to a particular utility function for the economy's agents provides a tractable alternative to the partial-equilibrium framework. Given a set of values for the model's parameters we can numerically compute equilibrium price, sales, output, and profits. Moreover, we can determine the sensitivity of social welfare to changes in the various parameters, which we do below.

2.2 Competitive Equilibrium

Using good two as the numeraire good, it can be shown that the competitive equilibrium price for good one is $P^*_{CE} = a_2/a_1$ in this environment. At this price, individuals are indifferent between producing good one and producing good two. Thus, there are many different labor and output allocations that allow the economy to produce and consume its preferred aggregate amounts of good one and good two.

In addition, any competitive allocation can be shown to be Pareto efficient.[11] At the competitive equilibrium, it is impossible to improve the well-being of any individual without making someone else worse off.

2.3 Monopoly Equilibrium

A license is required to produce good one. A group of individuals, each denoted m for monopolist, share such a license, and receive equal shares of the profits earned by the monopoly. 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. 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 $w = a_2$ in equilibrium.[12] The monopolists own all units of good one that are produced. 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 equation (1) for $h = m$.

The other individuals (the nonmonopolists) behave competitively given the price P and the wage rate w. They choose consumption amounts and a time 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 simple preference assumptions, it can be shown that a monopoly equilibrium (consisting of an equilibrium consumption, production, and labor allocation; a good-one price; and a wage) exists and is unique.[13] Monopolists are better off than in the competitive equilibrium, while most others are worse off.[14]

Affordability

Nonmonopolist h faces the affordability constraint $Pc_{1h} + c_{2h} \leq wl_{1h} + a_2 l_{2h}$. Since $w = a_2$ in equilibrium, and because the affordability constraint must be satisfied with equality in equilibrium, this relationship reduces to

$$Pc_{1h} + c_{2h} = a_2 l. \tag{2}$$

A monopolist m faces the affordability constraint

$$(a_2/a_1)c_{1m} + c_{2m} = a_2 l + (\pi^*/c), \tag{3}$$

where (π^*/c) is an individual monopolist's share of the total profits π^* generated by the monopoly.

Nonmonopolist Demand

Consumer h maximizes utility (equation (1)) subject to his or her affordability constraint (2). The nature of the utility function makes it likely that, at each price P, some individuals are willing to purchase good one while others are not. We define $\rho^*(P)$ to be the smallest value of ρ_h for which nonmonopolist h has 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 (4) and (5), respectively:

$$d_{1h}(P) = \begin{cases} \rho_h(a_2 l + P\sigma)/P - \sigma & \text{for } \rho_h > \rho^*(P) \\ 0 & \text{for } \rho_h \leq \rho^*(P), \end{cases} \tag{4}$$

and

$$d_{2h}(P) = \begin{cases} (1-\rho_h)(a_2 l + P\sigma) & \text{for } \rho_h > \rho^*(P) \\ a_2 l & \text{for } \rho_h \leq \rho^*(P). \end{cases} \tag{5}$$

An expression for $\rho^*(P)$ is derived from the first row of equation (4):

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

Let $D_1(P)$ be the 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,

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

When $\rho^*(P) \geq c$, the solution to this integral is[15]

$$D_1(P) = \frac{(a_2 l)^2}{2P(a_2 l + P\sigma)}. \tag{7}$$

Monopoly Sales, Price and Profit

A monopolist m also maximizes his or her individual utility ((1) for $h = m$) subject to his or her affordability constraint (3).

Letting $D_1^{-1}(q)$ be the price at which nonmonopolists demand in total the quantity q of good one, we rewrite equation (7) 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

$$D_1^{-1}(q) = \frac{a_2 l(\sqrt{q^2 + 2\sigma q} - q)}{2\sigma q}. \tag{8}$$

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

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

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

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

$$q^*_{1M} = -\sigma + \frac{\sqrt{4\sigma^4 + 8a_1 l\sigma^3 + 5a_1^2 l^2\sigma^2 + a_1^3 l^3\sigma}}{2(a_1 l + \sigma)}. \tag{9}$$

Combining equations (8) and (9) and defining the equilibrium monopoly price, P^*_M, to be $D_1^{-1}(q^*_{1M})$, we find that

$$P^*_M = \frac{a_2 l}{2\sigma}\sqrt{\frac{\sqrt{4\sigma^2(a_1 l+\sigma)+\sigma a_1^2 l^2}+2\sigma\sqrt{\sigma+a_1 l}}{\sqrt{4\sigma^2(a_1 l+\sigma)+\sigma a_1^2 l^2}-2\sigma\sqrt{\sigma+a_1 l}}} - \frac{a_2 l}{2\sigma}. \tag{10}$$

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

The monopolists' 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, equals q^*_{1M} plus the monopolists' consumption of good one. Subtracting the monopolists' own good-one production (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}):

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

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 minimum ρ_m value for which monopolist m has positive demand for good one. Specifically,

$$\rho_m^* = \frac{a_2\sigma}{a_2\sigma + a_1 a_2 l + a_1(\pi^*/c)}. \tag{11}$$

2.4 Comparative Statics 1

This section examines how monopoly price, sales, and profits are affected by changes in the five model parameters: a_1, a_2, l, σ, and c. Table 1 summarizes our results.[16]

An increase in the production technology for good one (a_1) decreases the monopoly's marginal production costs, which allows the monopoly to decrease the price it charges when selling good one. This lower price leads nonmonopolists to purchase a greater quantity of good one. However, the decrease in price is less than the decrease in marginal cost, so the net result is that monopolists are able to achieve higher profits.

[insert Table 1 here]

An increase in the production technology for good two (a_2) leads to a higher labor cost ($w = a_2$), which, from equation (10), causes the monopolists to charge a higher price for good one. However, an increase in a_2 has no effect on monopoly sales of good one. This occurs because the effect of the increase in income for nonmonopolists exactly offsets the effect of the higher price facing them. In fact, inspection of equation (9) reveals that the parameter a_2 is not a component of the computation of q_{1M}^*. It can be shown that the increase in price exceeds the increase in marginal cost, hence monopoly profits increase with an increase in a_2.

An increase in the labor resource l increases nonmonopolist income, which leads to an increase in demand for good one. This higher demand leads to an increase in both the price charged and amount sold by the monopoly. The higher price combined with the unchanged marginal cost means monopoly profits rise as well.

The lower σ is (that is, the greater the benefit consumers get from good one), the higher the price chosen by monopolists. Profits increase, although monopoly sales could be higher or lower – sales increase for relatively low values of σ and decrease for relatively large values. When σ increases from a low value consumers respond primarily to the lower price and purchase more. When σ increases from a high value consumers respond primarily to the decrease in the benefit obtained from good one consumption and purchase less.

Changes in the parameter c have no effect on price, sales, or on total monopoly profits. Since we consider only the case $\rho^*(P) \geq c$, changes in c have no effect on aggregate nonmonopolist demand for good one. Hence the monopoly has the same optimal price and sales, and its profits remain the same.

3 Welfare Analysis

In this section we compare social welfare under monopoly with social welfare under perfect competition. We examine how our results vary across different parameter values.

3.1 Utility Under Monopoly

First, for nonmonopolists, combining equations (1), (4) and (5) gives nonmonopolist h's utility as a function of price:

$$u_h(d_{1h}(P), d_{2h}(P)) = \begin{cases} \left[\frac{\rho_h(a_2 l + P\sigma)}{P}\right]^{\rho_h} \left[(1-\rho_h)(a_2 l + P\sigma)\right]^{(1-\rho_h)} & \text{for } \rho_h > \rho^*(P) \\ \sigma^{\rho_h}(a_2 l)^{(1-\rho_h)} & \text{for } \rho_h \leq \rho^*(P), \end{cases} \tag{12}$$

where $\rho^*(P)$ is as previously defined. Nonmonopolists whose utility parameter exceeds ρ^* consume a positive amount of good one. Those for whom $\rho_h \leq \rho^*$ consume none.

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.

3.2 Equivalent Variation

Our approach to welfare and distributional analysis is as follows. Using the utility an individual receives under perfect competition as a benchmark, we compute the proportional change in income (or equivalent variation) that would be required under monopoly in order for the individual to attain the same utility as he or she enjoys under perfect competition. Let $y_{CE,h}$ represent individual h's income in perfect competition, and let $v_{CE,h}(y_{CE,h})$ be the utility h obtains with that income.[17] Then, let $y_{M,h}$ be h's income under monopoly, and let $v_{M,h}(y_{M,h})$ be the utility individual h obtains under monopoly. By computing a value for γ_h in equation (13) below for each individual, we determine how much better or worse off he or she is as a result of monopoly:

$$v_{CE,h}(y_{CE,h}(1+\gamma_h)) = v_{M,h}(y_{M,h}). \tag{13}$$

The average of all individual equivalent variation values will be our aggregate measure of the benefit (or loss) of monopoly, Γ.

3.3 Comparative Statics 2

In a comprehensive numerical analysis, we found no combinations of the five parameters (a_1, a_2, l, c, and σ) such that $\Gamma > 0$. In other words, for each specific parameterization, operating the good-one sector monopolistically rather than competitively is equivalent to reducing each individual's income, on average, by the fraction Γ. This section examines how the social welfare difference, as measured by the aggregate equivalent variation value, Γ, is affected by changes in the five model parameters. Table 2 summarizes our results, while Figures 2 and 3 illustrate some of our findings.

[insert Table 2 here]

An increase in the production technology for good two (a_2) has no effect on aggregate equivalent variation. Indeed, it has no effect on individual equivalent variation for anyone in the economy. Consumers of good one experience both an increase in income and an increase in the relative cost of good one. As described in Section 2.4, the resulting income and substitution effects on good-one consumption are exactly offsetting. The conclusion is that changes in good-two productivity have no effect on social welfare.

A change in the portion of the population sharing in the monopoly profits, c, has no effect on aggregate equivalent variation. An increase in c means more individuals receive profits from monopolistic production and sale of good one, but the amount of profit received by each shareholder declines. The total amount of profit earned is unchanged so the total welfare gain experienced by monopoly shareholders is unchanged as c changes. Similarly, consumers of good one are only affected by changes in the price charged by the monopoly and the quantity available at that price, both of which are unaffected by changes in the portion of the population who are monopoly shareholders (see Table 1). Thus nonmonopolist welfare is unaffected by changes in c.[18]

We now turn our attention to the three remaining parameters, each of which does affect aggregate social welfare. With $a_2 = 150$, $c = 0.05$, and $\sigma = 50,000$, Figure 2 plots aggregate equivalent variation against the labor endowment parameter, l, for different values of good-one productivity (a_1). As shown by the downward slope of the lines, the welfare loss from monopoly increases (the absolute value of Γ increases) as l increases. In addition, increases in a_1 cause greater welfare losses from monopoly, as is illustrated by lower curves for higher values of a_1. With $a_2 = 75$, $c = 0.05$, and $l = 110$, Figure 3 plots aggregate equivalent variation against good-one productivity for different values of the utility parameter σ. We again see that the welfare loss from monopoly increases as a_1 increases. We also see that the welfare loss from monopoly decreases as σ increases. The remainder of this section gives some intuition for these observations.[19]

[insert Figure 2 here]

[insert Figure 3 here]

An increase in good-one productivity causes both the monopoly price (P_M^*) and the competitive price (a_2/a_1) to decline, thus encouraging current good-one consumers to purchase more as well as drawing more individuals into the good-one market. It can be shown (for all but the most extreme parameterizations) that the decline in the monopoly price is less than the decline in the competitive price, making the increase in good one consumption (and in new buyers) smaller under monopoly than under competition. In both regimes, nonmonopolists gain from being able to consume more good one. Under monopoly, some of this gain is transferred to monopolists as higher profits (see Table 1) and they keep the remainder for themselves. However, while receiving higher profits is

certainly of benefit to the monopolists, the flip side – payment of higher profits by nonmonopolists – is an equivalent loss for nonmonopolists meaning no net impact on aggregate equivalent variation. Meanwhile, because monopolists face the same price for good one under both competition and monopoly, an increase in good-one productivity produces identical substitution effects under both regimes for this group, which therefore produces no impact on aggregate equivalent variation. The net result is that the equivalent variation required to make individuals as well off under competition as they are under monopoly increases in magnitude (that is, the difference in consumer welfare between the two regimes increases) as a_1 increases.

An increase in the labor endowment, l, increases income for all individuals under both monopoly and competition. However, under monopoly this also causes an increase in the price of good one so the welfare gain is smaller here than in competition. Thus there is an increasing welfare difference, and an increase in the required equivalent variation value, between the two regimes as l increases.

An increase in the utility parameter, σ, primarily increases the minimum good-one purchasing threshold ρ^*, which decreases desired good one purchases under both monopoly and competition. The decline in desired good one purchases decreases the profits earned by the monopolists, and thus the welfare improvement monopolists experience under monopoly (relative to competition) declines as σ increases. For nonmonopolists, the fact that the good-one price is higher under monopoly than under competition means that good-one purchases fall less under monopoly. Thus the welfare losses experienced by nonmonopolists under monopoly (relative to competition) also decline as σ increases. The decline in the nonmonopolists' loss exceeds the decline in the monopolists' gain, so aggregate equivalent variation increases (becomes less negative) as σ increases.

4 Allocative Inefficiency in Pharmaceutical Markets

In this section we use our model to measure allocative inefficiency for four SSRI antidepressants (Celexa®, Lexapro®, Paxil®, and Zoloft®) and five atypical antipsychotics (Abilify®, Geodon®, Risperdal®, Seroquel®, and Zyprexa®) that were under patent in 2003. It is estimated that between 4.1 percent and 8.6 percent of the population in the United States suffer from depression (Miranda, *et al.*, 1994). In state Medicaid programs, the market share of the SSRIs among all antidepressants increased from eight percent in 1991 to 61 percent in 2003 (Guo, *et al.*,

2005a). These expensive medications have largely replaced tri-cyclic antidepressants, most of which are now off-patent.

Schizophrenia, which affects up to one percent of the population (McCombs, *et al.*, 2002) is a chronic, major psychotic disorder. The antipsychotic medications, which treat schizophrenia, bipolar disease, and other psychoses, are classified as either conventional (typical) or atypical. Most typical antipsychotics were developed in the 1950s. The introduction of clozapine (Clozaril®) in 1989 represented the first major advance in the psychopharmacologic treatment of schizophrenia in thirty years. Between 1994 and 2002, the FDA approved five additional atypical antipsychotics: risperidone (Risperdal®), olanzapine (Zyprexa®), quetiapine (Seroquel®), ziprasidone (Geodon®), and aripiprazole (Abilify®). In state Medicaid programs, the market share of atypical antipsychotics increased from one percent in 1991 to 86 percent in 2004 (Guo,*et al.*, 2005b).

Table 3 shows U.S. sales for each of the nine drugs in 2003.[20] The companies reported worldwide sales for all drugs, but reported U.S. sales specifically only for five of the drugs (Paxil®, Zoloft®, Geodon®, Seroquel®, and Zyprexa®). U.S. sales for the other four drugs were estimated based on the U.S.-to-world sales ratios for the other two antidepressants or three antipsychotics, respectively. Pfizer manufactures a relatively new atypical antipsychotic, Geodon®, with U.S. sales of $303 million in 2003 and the SSRI Zoloft®, expected to go off-patent in 2006, with 2003 U.S. sales of $2.5 billion. Forest Labs, Inc. manufactures two of the SSRIs, while the remaining companies (Otsuka America, Janssen Pharmaceuticals, Astrazeneca, Eli Lilly, and GlaxoSmithKline) sell one drug each in Table 3. The majority of schizophrenics are covered by Medicaid, hence, a large percentage of antipsychotic drug expenditures is borne by the public. In the year 2003, Medicaid reimbursements totaled $195.5 million for Abilify®, $157.4 million for Geodon®, $1.1 billion for Risperdal®, $740.6 million for Seroquel®, and $1.8 billion for Zyprexa® (Centers for Medicare & Medicaid Services).

[insert Table 3 here]

In order to apply our model to the estimation of social-welfare loss for the antidepressant and antipsychotic medications, we chose appropriate values for a_1, a_2, and l, based on empirical observation of the United States economy. Since Γ is independent of c, we simply selected a small

value for c and maintained it throughout the calibration. To complete calibration of the model, we chose σ to produce the same expenditure share for an individual drug as observed in the United States economy for 2003.

We computed l from data provided by the Bureau of Labor Statistics (BLS) as follows. 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.

We determined a_2 by dividing national value added (GDP) for 2003, \$11,004 billion, by the total number of hours worked per year, found by multiplying the 2,943.6 million hours per week by 52 weeks. This calculation gives us a value for a_2 of \$71.89. To find the value for a_1, we referred to United States manufacturing data in the *2002 Census of Manufactures*. Total value added by manufacture for Pharmaceutical Preparation Manufacturing (NAICS industry 325412) was \$83.6 billion. Dividing by number of hours worked (360.8 million) gives value added per hour of \$231.62 in 2002 dollars. However, this figure includes significant price inflation relative to our estimate for a_2. Hence, we deflate 2002 value added per hour using the producer price index for pharmaceutical preparation manufacturing to obtain value added per hour in 1982 dollars. We then reinflate that value back to 2003 using the finished-goods PPI to be consistent with our measurement of a_2. The value for a_1 obtained in this manner is \$110.68.

To complete our calibration, we divide U.S. sales of each drug by U.S. GDP to get the share of national income spent on each drug. We select σ for each drug such that the model produces a similar national expenditure share.

After selecting values for the model parameters, we used the model to compute Γ, the average equivalent variation. Multiplying Γ by national income (GDP) gives the aggregate welfare loss for each drug. Table 4 shows that the social welfare losses for 2003 were substantial, ranging from \$63.5 million for Abilify® (one of the newest of the nine drugs) to \$658.4 million for Zyprexa®. However, just as the drug development process takes many years, the economy suffers social welfare loss for many years as well – the average duration of on-patent sales is approximately ten years. Some of our drugs (Abilify®, Geodon®, and Lexapro®) have recently entered this ten-year period, while

the patents on others (Paxil®, Zoloft®, and Risperdal®) are nearing expiration. Since our drugs span the typical ten-year patented life of a branded pharmaceutical product, it is reasonable to average the social welfare losses across the nine drugs to determine a typical social welfare loss. Multiplying this average by ten gives a multi-year social welfare loss of $3.4 billion for a typical branded pharmaceutical in these two mental-health drug classes.[21] Adding this figure to the $0.8 billion in estimated drug development costs gives a total cost for each drug of approximately $4.2 billion. On average, the benefits of the drug must exceed this cost in order to justify the current patented-monopoly research, development, and production system.[22]

[insert Table 4 here]

5 Conclusion

Partial-equilibrium models fail to capture all of the allocative effects of monopoly by neglecting the interactions that occur between monopolistic and other sectors. The two-good general-equilibrium monopoly model introduced in this paper incorporates potential intersectoral interactions, while also incorporating monopoly shareholder utility. This model is a straightforward extension of a perfectly competitive general-equilibrium framework, with the monopoly in one sector arising from a production restriction. The model is particularly applicable to pharmaceutical markets since it incorporates a licensing, rather than increasing-returns-to-scale, rationale for monopoly.

The model requires no specific form of the utility function. However, for the additional tractability desired to address pharmaceutical policy issues, we identify a specific utility function that satisfies the required preference assumptions. Doing so allows us to assess the sensitivity of key model aggregates to variations in parameter values. We use average equivalent variation in income as our measure of the social welfare difference between monopoly and competition. We find the welfare loss due to monopoly increases the greater the labor productivity of the monopolistically produced good, the greater the labor endowment, and the greater the consumers' need for the monopolistically produced good. Changes in other-good productivity and the proportion of monopoly shareholders have no effect on aggregate social welfare.

After calibrating our model to macroeconomic data for the United States economy and to sales data for nine relatively new antidepressant and antipsychotic drugs, we use our model to determine that patented monopoly has a nontrivial effect on social welfare. In 2003, monopolistic production of each of the drugs caused at least $60 million in social welfare loss. Two of the drugs exhibited over $600 million in allocative inefficiency. When added to the average cost of new drug development, our average allocative inefficiency estimate brings the total new-drug cost to approximately $4.2 billion. In drug policy debates, especially concerning optimal patent length and ways to encourage manufacturers of generic drugs to enter the market after patent expiration, it is this total cost – private plus social – that is most relevant to the discussion.

Notes

[1]According to the Bureau of Labor Statistics (BLS), the producer price index (PPI) for finished goods grew at an average annual rate of 1.7 percent from 1982 to 2003. The PPI for pharmaceutical preparation manufacturing grew at an average annual rate of 5.5 percent over the same time period. The PPI for central nervous system stimulants grew at an average annual rate of 9.4 percent from 1982 to 2000 (latest available year for this series), while the PPI for psychotherapeutics grew at an average annual rate of 13.7 percent over the 1982-to-2000 period.

[2]Although research and development costs have risen annually at the rate of 7.4 percent above inflation in the past decade (see DiMasi, Hansen, and Grabowski, 2003), this rising expense alone cannot account for the double-digit annual increases in pharmaceutical expenditures.

[3]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 $3,600; and catastrophic coverage thereafter with a small co-pay. 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").

[4]These benefits are usually difficult to measure in advance of drug development. In one attempt, McGuire (2003) estimates the expected benefits of the development of particular vaccines.

[5]Harberger estimated the deadweight loss due to market power for 73 United States manufacturing industries. He found DWL to be a very small percentage of national income. The Cowling and Mueller (1978) study, using firm- rather than industry-level data, found DWL to be much larger—in fact, up to ten times as large as Harberger's estimates. A discussion of methodological and empirical issues surrounding DWL estimation can be found in Littlechild (1981) and Jenny and Weber (1983). See Waldman and Jensen (2001) for a textbook treatment of DWL and other social-welfare costs of monopoly.

[6]Kelton and Rebelein (2005) show that the welfare gains possible with universal insurance are small relative to the allocative efficiency loss due to monopoly. Further, our general-equilibrium

model omits explicit consideration of R & D expenses. Our purpose, however, is to come up with the cost to society of a monopoly market structure. This cost must be added to the cost of R & D (the $800 million from DiMasi, Hansen and Grabowski, 2003) to estimate the *total* cost of the drug. This total can then be compared to the benefits to society of the new, higher-quality medicine the monopoly structure brings through the R & D process. Future work may allow a model that captures both static and dynamic monopoly costs simultaneously.

[7]Results in Guo, *et al.* (2004) and Dusing, *et al.* (2005) indicate that interbrand competition does little to reduce the list or transaction prices of other branded medications, hence, we choose a monopoly rather than an oligopoly specification of the market. Only when direct generic-drug-company competitors of the branded drug enter a market do consumers and insurers see significant price declines.

[8]The model builds on the framework developed by Kelton and Wallace (1995). Relevant material is found in Chapters 7 and 16, which are available from the authors on request.

[9]The assumption that all individuals possess identical technologies is a simplifying assumption. It is not needed for proving existence or uniqueness of the competitive equilibrium, but is useful for the analysis of monopoly. Situations of one or a few sellers arise naturally if the technologies are such that only a small number of individuals are capable of producing one of the goods.

[10]We thank Xiangkang Yin (2001) for suggesting this utility function, which is a generalization of the Cobb-Douglas function. A significant feature 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. Note that $u_h(\cdot,\cdot)$ satisfies $u_{h1} > 0$ and $u_{h2} > 0$, and the matrix of second derivatives is negative semi-definite.

[11]See Kelton and Wallace (1995), Chapter 7.

[12]At $w = a_2$ nonmonopolists are indifferent between working for themselves to produce good two or working for the monopolists.

[13]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, defined below for the monopolists, is strictly concave. The third assumption

ensures 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. As is the case for the competitive equilibrium, we have nonsignificant multiplicity of equilibrium labor and output pairs. In fact, even aggregate employment of nonmonopolists is not uniquely determined since monopolists are free to substitute some of their own labor for the labor of non-license holders. The monopoly allocation is not Pareto efficient. One of the necessary conditions for Pareto efficiency is violated since the monopoly price exceeds the marginal rate of transformation of good-two producers.

[14]Unless there is a tax (or some other fee) to finance a universal insurance program, nonmonopolists whose need for good one is low enough such that they do not consume it under either monopoly or competition are indifferent between the two regimes.

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

[16]The comparative-static effects were obtained using a combination of analytical and numerical techniques.

[17]For nonmonopolists, under either perfect competition or monopoly, $y_{CE,h} = a_2 l$, while for monopolists under monopoly, $y_{M,m} = a_2 l + (\pi^*/c)$.

[18]The single exception occurs when c gets large enough to include some good-one consumers (i.e., when $c > \rho^*$). An increase in c that changes a good-one-purchasing nonmonopolist into a monopoly shareholder reduces monopoly sales to nonmonopolists and thus reduces the monopoly's profits. The result is a decline in the welfare gain experienced by monopolists.

[19]Subsequent calibration work indicates that the parameter values chosen are not out of line with values for the United States economy.

[20]Data are taken from the various companies' annual reports and accompanying documents.

[21]We recognize that this average will probably differ for other therapeutic classes. Future research could examine a broader set of pharmaceutical products.

[22]Price discrimination in pharmaceutical markets, as described in Danzon and Towse (2003), is one method of decreasing these social welfare costs.

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Figure 1: A Monopoly Market

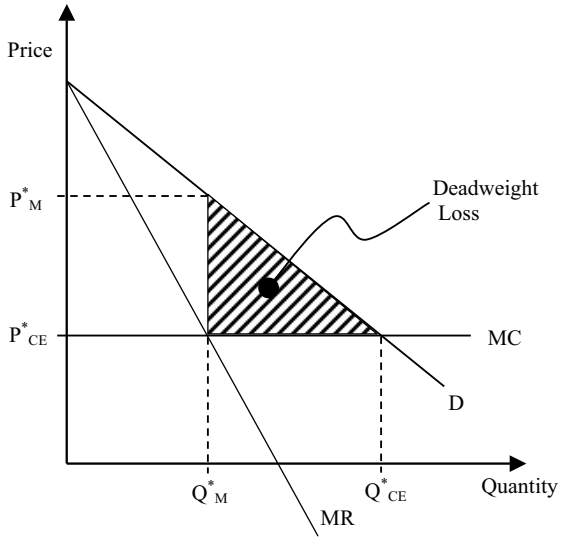

Table 1: Comparative Statics

	a_1	a_2	l	σ	c
Monopoly Price	$-$	$+$	$+$	$-$	0
Monopoly Sales	$+$	0	$+$	$+/-$	0
Total Profits	$+$	$+$	$+$	$-$	0

Table 2: Effect of Parameter Changes on Aggregate Equivalent Variation (Γ)

	a_2	c	a_1	l	σ
Γ	0	0	$-$	$-$	$+$

Table 3: United States Sales in 2003 for Nine Patented-Drug Monopolies

Drug	Manufacturer	United States Sales ($ millions)
Celexa®	Forest Labs, Inc.	777.7
Lexapro®	Forest Labs, Inc.	778.9
Paxil®	GlaxoSmithKline	1,927.7
Zoloft®	Pfizer	2,502.0
Abilify®	Otsuka America	254.7
Geodon®	Pfizer	303.0
Risperdal®	Janssen Pharmaceuticals	2,033.4
Seroquel®	Astrazeneca L.P.	1,131.0
Zyprexa®	Eli Lilly & Co.	2,640.0

Figure 2: Equivalent Variation vs. l for different a_1 values

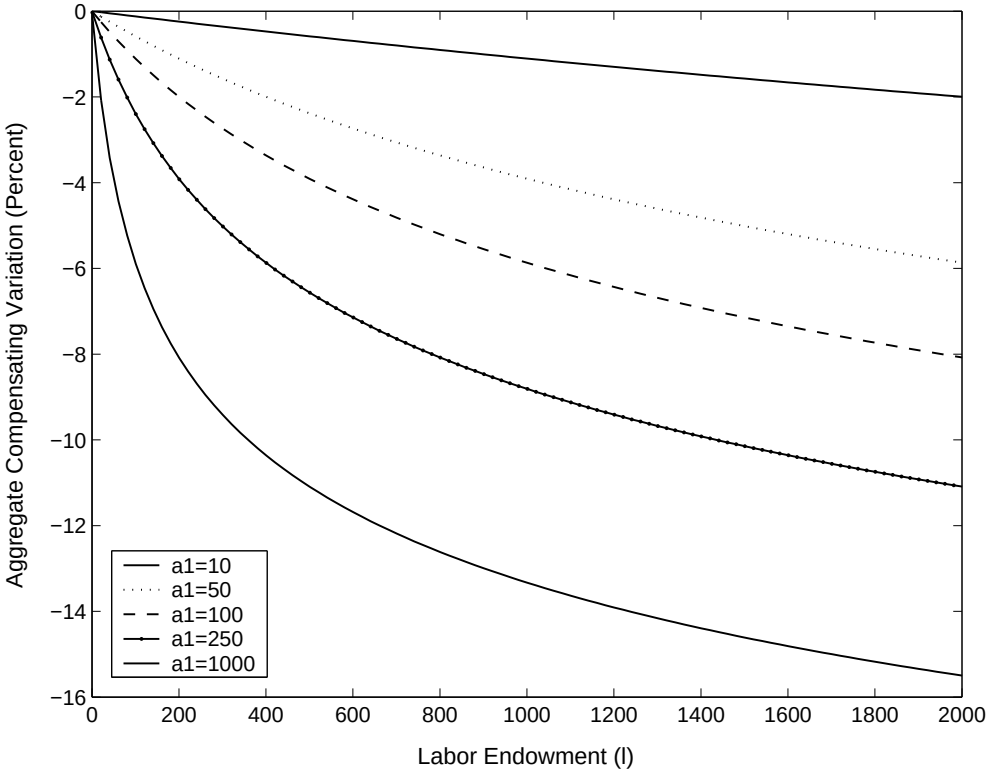

Figure 3: Equivalent Variation vs. a_1 for different σ values

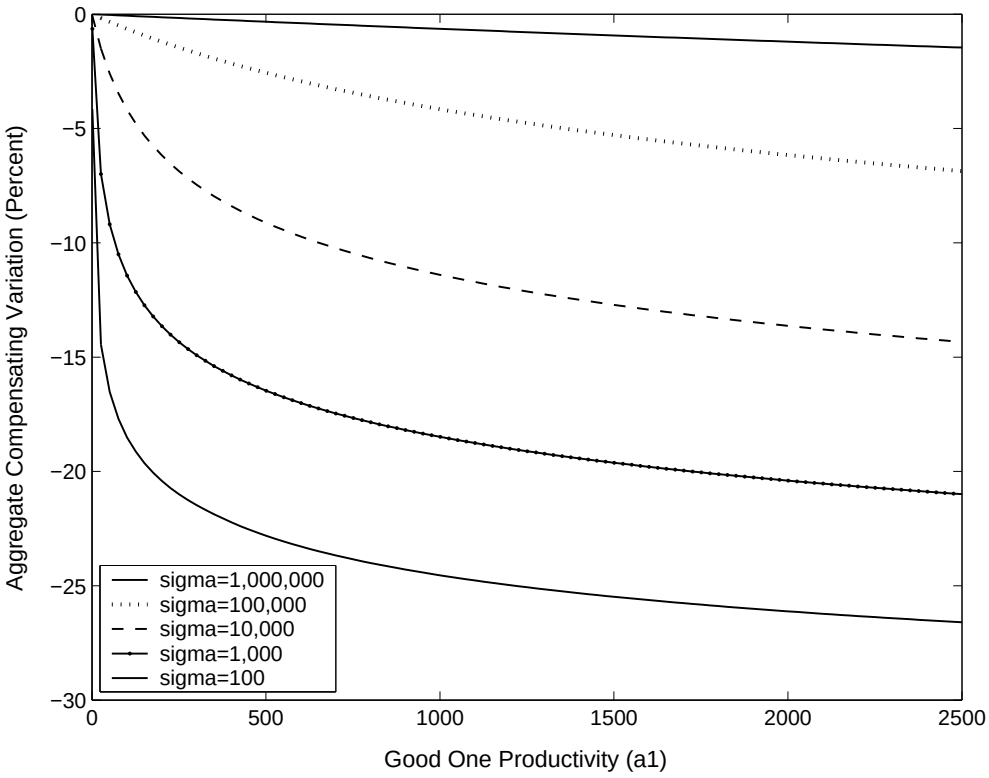

Table 4: Social Welfare Loss for Nine Patented-Drug Monopolies in 2003

Drug	σ	Γ	Social Welfare Loss
Celexa®	462,661,000	−0.000017626	$193,957,000
Lexapro®	461,948,000	−0.000017653	$194,254,000
Paxil®	186,602,000	−0.000043691	$480,776,000
Zoloft®	143,745,000	−0.000056709	$624,026,000
Abilify®	1,412,930,000	−0.000005772	$63,515,000
Geodon®	1,187,697,000	−0.000006867	$75,564,000
Risperdal®	192,145,000	−0.000042431	$466,911,000
Seroquel®	318,112,000	−0.000025633	$282,066,000
Zyprexa®	136,226,000	−0.000059837	$658,446,000