Toward Allocative Efficiency in the Prescription Drug Industry

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CAN ECONOMIC REGULATION OF THE U.S. PHARMAceutical industry improve economic efficiency? There is widespread populist sentiment that pharmaceutical companies are gouging the public and that something should be done about it. The conventional wisdom among economists is that although the industry does enjoy monopoly profits, standard accounting practices, when applied to the pharmaceutical industry, overstate profits (Scherer 1993). Given the unique cost structure of the pharmaceutical industry, however, profit measures may substantially understate the costs of the price distortions that result from the exercise of monopoly power. The dramatic difference between the price of a dose and its marginal cost (the additional cost of producing one more dose) leads to heavy expenditures in directions that only slightly increase profits and that provide little value to consumers. These "rent-seeking" activities include intensive marketing efforts, aggressive approaches to litigation, and a willingness to capitalize expected monopoly profits when acquiring drug distribution channels. The deadweight loss (DWL) of consumer surplus—a measure of the degree to which consumer losses from higher prices are not offset by greater revenue to producers—offers an alternative approach to

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measuring the efficiency costs of monopoly power. We will pursue this approach in order to reveal a darker picture of wasted resources than emerges from the conventional portrait.

Price controls are the populist remedy for excessive monopoly power. Economists believe that price controls, by inhibiting profit potential, would stifle investment in research and development (R&D). Further, the social payoff from drug innovation can be extremely high, especially because alternative treatment modalities may be not only less effective, but also more expensive and more invasive. Thus, the costs of restricting profits in the pharmaceutical industry are potentially very large and inherently impossible to measure precisely. We will attempt to bypass this problem by investigating whether global economic efficiency could be improved by changing the rules of the game under which the pharmaceutical industry operates. Specifically, we propose an alternative to price or profit controls whereby the government would purchase patents for pharmaceutical innovations and issue licenses freely, at no cost for distribution of the product in the United States. (Licenses for foreign production would be freely granted at a price approximating the expected average cost of R&D.) The efficiency loss from raising the requisite taxes to subsidize this approach is compared with the existing efficiency loss from the exercise of monopoly power in the industry.

The analysis proceeds in four steps: First, we review the literature. Second, given the structure of the pharmaceutical industry, we argue that a consumers' surplus approach provides a better indicator of efficiency loss from the exercise of monopoly power than does a measure of monopoly profits. Third, we develop two different measures of the DWL associated with monopoly activity in the pharmaceutical industry. Fourth, we measure the DWL associated with the government's raising sufficient funds to compensate pharmaceutical companies for the loss of monopoly profits.

If the DWL associated with monopoly activity is greater than that associated with raising sufficient revenue to purchase the patents at a price equal to the expected net present value of the future monopoly profits, then this policy option should be considered viable, and should inspire further, more detailed investigations of the industry and of alternative policy options. What follows should therefore be viewed as an exploration into establishing sufficient grounds for modifying incentives in the pharmaceutical industry.

Conventional Views: Populism and the Academic Response

If one is looking for corporate villains, the pharmaceutical industry provides an inviting target. Many products enjoy strong monopoly positions, and prices to different customers can easily vary by at least a factor of ten. On the other hand, if one is looking for corporate heroes, the pharmaceutical industry offers outstanding examples. Whereas most new technologies in the health care sector lead, at very great expense, to rather modest improvements in health status, new medications often substantially improve health status, and, at the same time, reduce aggregate health care expenditures. Two questions emerge: First, is it correct to infer from the variance in pricing that the industry is a source of substantial static allocative inefficiencies? Second, can static inefficiency be addressed without impairing either the motivation to engage in research and development or the flow of medicinal innovations?

Congressional hearings initially sponsored by Senator Kefauver, and later by Senator Nelson, explored the populist topic of imposing price or profit controls on the pharmaceutical industry, a subject that has been revived recently by Senator Pryor and Congressman Waxman. It might be useful to summarize the populist case: First, rampant health care cost inflation, which has pushed health care expenditures to 14 percent of the GDP, has led to increased demands to control costs in any way possible. Second, anecdotal evidence of dramatic price differences between branded and generic versions of a drug supports the belief that pharmaceutical prices are excessive. Third, and more generally, drug price indices indicate that over the past decade prices of prescription drugs have risen at more than twice the rate of inflation (Scherer 1993). Fourth, data on Fortune 500 firms consistently show that, for any relevant period chosen, the rates-of-return for drug manufacturers are well in excess of the average industry, despite mild fluctuations in aggregated year-to-year earnings (Scherer 1993). Finally, several new studies (Johnston and Zeckhauser 1990; Kolata 1991; U.S. General Accounting Office 1992, 1994) have found drug prices in the United States to be substantially higher than prices of similar or identical drugs in other countries—evidence that controls can lead to lower prices.

Pharmaceutical companies view the issue differently, and their lack of enthusiasm for controls is generally shared by academic economists.

Reining in drug prices is hardly the key to containing health care costs in general. Because prescription drugs are often paid for out of pocket, and because payments for pharmaceuticals are more widely dispersed than payments for other forms of health care, public perception exaggerates the share of the health care dollar going to pharmaceutical companies. Additionally, treatment with drugs is often far less expensive than more invasive alternatives.

Defenders of the pharmaceutical industry have a response to each populist charge. Drug price indices have problems; they have been shown to be almost irrelevant for determining the change in the true price of drug therapy because of the way generic drugs are treated in creating the indices (Comanor 1986; Berndt, Griliches, and Rosett 1993). Conventional accounting may overstate industry profits; a substantial literature (Stauffer 1971; Clarkson 1977, 1979; Baber and Kang 1991; U.S. Office of Technology Assessment 1993) has shown that because R&D is expensed, rather than depreciated, accounting rates of return often exceed economic rates of return by a substantial margin. Finally, the fact that the price of most directly comparable formulations is substantially higher in the United States than elsewhere can be viewed as a problem of the commons. A reduction in price will lead to decreased investment in inventive activity. In a global marketplace, a given reduction in price in a small country imposes smaller negative spillovers on inventive activity than would a similar action in a larger country. Introducing price controls in the United States, it is argued, would severely constrain available R&D money for all drugs everywhere.

The Degree of Allocative Inefficiency

One reason for investigating alternatives to price and profit regulation is that popular instincts regarding the costs of the status quo may be better than the conventional instincts of economists. The press and the politicians focus on anecdotal evidence of huge differences in price either between generic and branded products or between the United States and overseas. Economists engage in sometimes arcane disputes over the real rate of economic profit in the industry—where the issue may be over different degrees of small.

To an economist monopoly profits per se are not a cause for concern. The problem is that, in order to garner those profits, monopolists set

price above marginal cost and produce less than the socially desirable output. Monopoly profit provides only an indirect indicator of the loss of allocative efficiency that results from the exercise of monopoly power. Producers exercise monopoly power by setting price above the competitive level. What does concern economists is the DWL, or the fact that consumers lose more from higher prices than producers gain.

The use of the concept of consumers' surplus to measure changes in material well-being is somewhat controversial among economists. There is a consensus that the use of consumer's surplus is entirely appropriate when applied to the demand curve of an individual (Willig 1976; Hausman 1981). Additional concerns arise, however, when data are aggregated, that is, consumers' surplus versus consumer's surplus. One set of concerns about the use of partial equilibrium analysis is not critical to our application, as we are dealing with a "small" industry. A more substantive issue is the assumption implicitly underlying the analysis that a dollar is a dollar, or that Miss B gets the same satisfaction from spending an additional dollar that Mr. A does. Recognizing these problems, most, but not all, economists still believe that consumers' surplus is the best available tool for empirical work evaluating allocative efficiency (Morey 1984; Harberger 1971; Ekelund and He'rbert 1985).

An estimate of the DWL of consumers' surplus from the exercise of monopoly power requires a determination of the monopoly price—P_1 in figure 1—in addition to an estimate of the price had the industry been purely competitive—P_2 in figure 1-and also an estimate of the demand schedule—the amount that consumers would buy at each price in a set

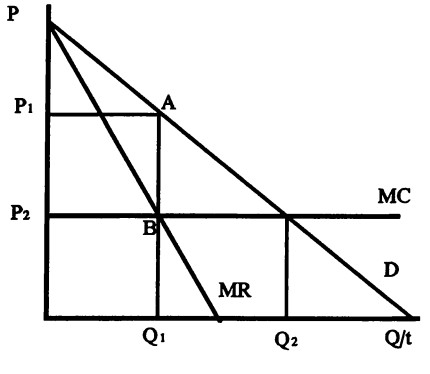

FIG. 1. Monopoly versus competitive pricing.

of possible prices. Thus, two of the three variables involve hypothetical or counterfactual data. The structure of the pharmaceutical industry, combined with simple economic theory, provides surprisingly powerful help. Two factors help place an upper bound on the estimate of competitive price: First, faced with high fixed costs, low variable costs, and separable markets, pharmaceutical firms engage in price discrimination. They sell the same product at different prices in different markets. These products have a very high value per pound, and so, with negligible transportation costs, the cost of delivering a product should not differ significantly from place to place. Second, the only reason to sell a product below marginal cost is predatory pricing—a strategic move to drive competitors out. This motivation clearly does not apply to a pure monopolist, and does not appear to be a significant concern, given the structure of the pharmaceutical industry. By combining the two factors, it can be reasonably presumed that the lowest price at which a drug is sold, in any market, is no lower than marginal cost, and therefore no lower than the price to all customers were the product to be sold in a competitive market.

The more elastic the demand, the greater the increase in sales, and therefore the greater the increase in consumers' surplus, from a given reduction in price. Profit-maximizing firms would never operate on the inelastic portion of their demand curves, and so an assumption of unit price elasticity provides a lower bound estimate of the loss associated with monopoly pricing.

We further assume constant returns to scale in the manufacturing process (hereafter called the CRS assumption). This makes marginal cost constant not only across space, but also across quantity. This is again a reasonable assumption given the character of the industry.

One additional issue is that although compensated demand elasticities are indicated for the purpose of analyzing efficiency, Sullivan (1992) estimated the income elasticity of demand for drugs among the elderly population and found it to be not statistically different from zero. For this reason, we believe that compensated and uncompensated elasticities are likely to be identical.

Given the theoretical properties of a profit-maximizing monopoly firm and the CRS assumption, a lower bound estimate of DWL is measurable with data on price discrimination. A recent report by the U.S. General Accounting Office (1994) provides just that kind of data. An examination of the 200 drugs most frequently prescribed in the United

States produced 77 that were sold by the same company, in the same strength, and in a comparable dosage form in the United Kingdom. The study looked at cost per pill, using the most common package size in the United States and comparing it with the same or the closest smaller package size in the United Kingdom. It is important to note that by comparing products purchased in volume in the United States, rather than in the United Kingdom, by weighting according to importance in the United States, and by using exchange rates rather than purchasing power parity, the estimated price differential was biased in a downward direction. This is important for our purposes because we seek as conservative an estimate of DWL as possible. Further, the GAO study looked only at the standard factory price and not at discounted prices that the federal government and other large purchasers receive, and it looked only at branded products, not generic equivalents. The report estimates that at least 55 percent of the $48.9 billion ($26.9 billion) sales in outpatient prescriptions are filled from product not discounted by the factory (U.S. General Accounting Office 1994, 4). The average nondiscounted wholesale price in the United States was 60 percent higher than the average wholesale price in the United Kingdom (U.S. General Accounting Office 1994, 5)—although one in seven drugs was priced lower in the United States than in the United Kingdom. Since the argument is that allocative inefficiency results when price exceeds marginal cost, and that the *lowest* price charged for a product is an upper bound estimate of marginal cost, inefficiency is present whenever prices differ—whether the lowest price is in the United States, in the United Kingdom, in some third country, sold to the government, or sold as a generic. Using the *average* markup of the U.S. over the U.K. price, therefore, again understates the magnitude of the distortion.

The DWL, illustrated graphically in figure 2, can be mathematically represented as $= \frac{1}{2}(P_1 - P_2)(Q_2 - Q_1)$. Based on the 1994 GAO report and the at-least-unitary elasticity assumption, we estimate that the static DWL associated with monopoly power in prescription drugs can be no lower than $3.02 billion (see Appendix 1).

A less conservative estimate of DWL relies on the fact that high markups, which stem from monopoly power, may bring about higher costs. Marketing cost estimates that run from 15 percent of sales (Pharmaceutical Manufacturers Association 1988) to 22 percent of sales (Ballance, Pogany, and Forstner 1992) clearly indicate the presence of monopoly rent-seeking behavior. Additionally, because Ballance, Pogany, and Forstner estimate

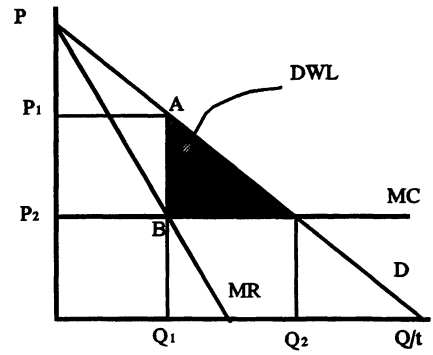

FIG. 2. Deadweight loss from monopoly pricing.

production costs at only 35 percent of sales, using the Dorfman-Steiner rule that the marginal revenue from an extra dollar of marketing effort should equal a dollar times the elasticity of demand (Mansfield 1994), it is apparent that the pharmaceutical industry is acting rationally when it energetically pushes marketing efforts. Thus, much of the rectangle, P_2P_1AB, represents not a transfer of income from consumers to producers, but, rather rent-seeking activities that add to the industry's inefficiency.

Our second estimate of the DWL from the exercise of monopoly power in the pharmaceutical industry, therefore, may be obtained by making an assumption that manufacturing costs per unit represent the bulk of marginal costs apart from those marketing costs, which are in turn a function of monopoly rents. Using the estimate by Ballance, Pogany, and Forstner (1992) of direct manufacturing costs, \$29.51 billion may be viewed as an upper bound estimate of the DWL from monopoly power in the pharmaceutical industry (see Appendix 2).

Policy Options and Our Proposal

Economists argue that, apart from the equity considerations involved, the metric by which policy options should be judged is the result of the policy on economic efficiency, especially allocative efficiency. Among themselves, economists, without much discussion, almost uniformly look askance at price and profit regulation. Economists, at least, have long held that this policy is more injurious than the problems it attempts to

address. On the other hand, one reason for investigating alternatives to price and profit regulation is that popular instincts regarding the costs of the status quo may be more accurate than the narrow view of economists. The press and the politicians focus on instances of huge differences in price between generic and branded products, or between prices in the United States and overseas, using them to argue the "fairness" issue in pharmaceutical prices. We believe that our policy proposal would favor both efficiency and equity concerns.

The search, then, is for a policy that will both increase efficiency and lead to lower prices for consumers. To demonstrate an unambiguous improvement, static efficiency (efficiency in the current time period) must be separated from dynamic efficiency (efficiency over many time periods). Dynamic efficiency concerns are too often overlooked because their effects are difficult to nearly impossible to measure. Regarding prescription drugs, dynamic efficiency is achieved only if the R&D of new or improved drugs exists at the optimal level. In order for a policy to make an efficiency improvement, it must do one of the following:

1. Improve static efficiency to the extent that it overwhelms any reduction in dynamic efficiency
2. Improve dynamic efficiency to the extent that it exceeds any possible loss of static efficiency
3. Improve one without affecting the other

By most accounts, the policies that restrict either price or profits may improve static efficiency, but only at the cost of dynamic efficiency (U.S. General Accounting Office 1994). Because the reduction in dynamic efficiency cannot be accurately measured (it would be necessary to know what diseases went untreated or whose treatments were delayed in order to assess the economic impact of the reduced R&D), it may well be inherently impossible to make a clear efficiency case for price or profit controls. Instead, we will attempt to construct a policy option that appears to have a neutral impact on dynamic efficiency in order to evaluate static efficiency implications more accurately.

We propose that the government buy prescription drug patents at a price equaling the net present value of the profit they would have generated and distribute the patents to U.S. drug manufactures. In this way, static efficiency is improved because individual firms would each produce the drug at a price close to its marginal (manufacturing) costs.

Dynamic efficiency would be unaltered because it is precisely the net present value of monopoly profits that initially inspired the search for the new or improved drug. The inefficiency associated with the increased taxes necessary to pay for the patents would be less than the original monopoly-generated inefficiency.

The first step in evaluating this proposal is to determine whether it is better than its more conventional alternatives, the first of which is to place price controls on prescription drugs. This alternative, employed in many developed and undeveloped countries, can, and usually does, improve both static efficiency (by bringing price closer to marginal cost) and equity (by bringing price within reach of most people), but at a cost of dynamic inefficiency. A 1994 U.S. General Accounting Office report clearly indicates that countries with price controls see less R&D of drugs, which leads to dynamic inefficiency. Because this inefficiency is immeasurable, the question of whether the improvement in static efficiency and equity is enough to counter it is unanswerable. Further, an absence of a measurable effect of price controls on R&D in smaller markets would not necessarily provide support for price controls in the United States because these are clearly "beggar-thy-neighbor" policies, which allow other nations to benefit from high U.S. prices. If high U.S prices serve to motivate drug research globally, the existence of price controls in a "small country" would have minimal impact on the level of R&D investment in that country. Because the United States provides the largest national market for pharmaceuticals, price controls here would have a very different impact; it would induce a significant drop in R&D not only in the United States, but elsewhere as well.

Precisely the same set of problems bedevils profit controls because they manifest themselves as price controls. Again, although profit controls may lead to measurable static benefits, dynamic costs may be potentially large and basically unknowable.

The second step is to compare the static efficiency of policies that may be dynamically neutral. Essentially, this means comparing approaches that should not materially change either the rate or the composition of new drug development. Present policy encourages new drug development by providing limited term patent monopolies. All alternative policies must also involve an element of government intervention. When the government determines that a good is in the public interest, it can build (hire inputs and directly organize production) or it can buy. Buying a product at a fixed, predetermined price is one alternative, which can lead to cost minimization without regard to quality. Experience with de-

fense and space agency procurement illustrates that, if technology is not in place to produce the good, this approach may be a recipe for disaster. The failure of the Mars Observer provides one object lesson. A review committee appointed by the National Aeronautics and Space Administration (NASA) explicitly cited fixed cost pricing to be at least part of the problem. The review committee's chair stated that the incentive structure led to inadequate testing and a consequent fuel line rupture (CNN 1994). Because developing new chemical entities is like building space vehicles—both are subject to innovation uncertainties—their estimated costs are subject to large variances. An R&D contest with a fixed award would be risky for entrants and would encourage shortcuts.

Alternatively, both the defense department and NASA have tried buying on a cost-plus basis, whereby price is flexible and equal to the cost of development plus some profit. Almost invariably this results in cost overruns because the builder does not share in the savings. An example would be the Air Force's Advanced Medium Range Air to Air Missile (AMRAAM) program, whose projected cost quintupled over time (McNaugher 1986).

In using either procurement mechanism to develop new drugs, not only are incentives for achieving static efficiency reduced or misplaced, but dynamic efficiency is also sacrificed, either because the level of R&D spending is too low (as with fixed cost pricing) or because R&D dollars produce less (as with cost-plus pricing).

When the government builds—when it does research in house—it faces all the disabilities of cost-plus pricing and provides even fewer incentives for ultimate success.

Paying the net present value of future monopoly profits avoids these difficulties. Because firms looking for NCEs would be doing so based on the drugs' profitability, their incentive structure would be no different than under the current regulatory regime. It is at least conceptually possible to demonstrate that a clear net social benefit derives from our proposal, whereas the inherent uncertainties in dealing with dynamic efficiency make it impossible to prove such a benefit with conventional alternative policies.

The third step is to investigate whether societal gains from improved static efficiency will more than offset the excess social costs of raising funds through taxation. Eliminating from consideration the politically impossible lump-sum tax leaves a per unit tax on drugs as the obvious choice of a tax to pay for the patent. Apart from reduced rent-seeking activities, this, unfortunately, would leave DWL precisely equal to what

it is with monopoly production and distribution of drugs. If a tax could be found that has a lower DWL than the monopoly DWL in prescription drugs, it could then be raised and the revenue applied to prescription drug patent buying. Based on the rate of profit on sales provided in the report by Ballance, Pogany, and Forstner (1992), we estimate profits as being in the neighborhood of $8 billion. With that, our estimates of DWL, as falling between $3.02 billion and $29.51 billion, point to DWL per dollar of monopoly profits ranging from 38 percent to 369 percent. Jorgenson and Yun (1990) have estimated the DWL per dollar of labor income taxes to be 30 percent. (Deficit finance [Barro 1979] or a value-added tax [Ballard, Scholz, and Shoven 1986] would lower tax-induced DWL.) Thus, under either estimate, efficiency is improved, but the level of support for intervention in this manner depends heavily on the DWL estimate chosen.

The fourth step is to look at the impact of the proposal on the equity issues that concern politicians and the press. Drug prices to consumers would fall substantially, so equity would improve absent any highly inequitable approach to financing the scheme. Although not all drugs will be affordable to all consumers—those drugs with high manufacturing costs will still be beyond the reach of some people—prices will be reduced, on average, by 65 percent (again using the estimate by Ballance and colleagues of manufacturing costs).

The last serious remaining difficulty, then, is to come up with a scheme for determining the expected net present value of future monopoly profits. Determining the level of monopoly profits of a proposed drug would be difficult for a multitude of reasons, not the least of which are that the ultimate effectiveness of the new drug is uncertain and the newly invented drug may be more valuable than the one sought. (In medical research the unintended beneficial qualities of medicines are often as important as the intended ones. Temin [1980], for example, relates how research on sulfa drugs led to whole new classes of therapeutic agents, including tranquilizers and antihypertensives.)

As a result, the negotiation for the value of the patent will have to be done after the drug is approved. Clearly, the firm will argue that profits will be very high and the buying agency will argue that profits will be very low. Early in the history of this type of program the immediate past observed behavior of customers and firms would help in determining the expected net present value of monopoly profit (ENPVMP). Later, with no actual monopoly market to observe, it would be difficult, if not impossible, to determine the ENPVMP.

This problem brings us to the issue of eminent domain. When the government wishes to confiscate a private good for public use, the Fifth Amendment to the Constitution of the United States mandates that the holder of the private good be given "just compensation." In eminent domain cases wholly unqualified judges determine the "just compensation" based on two competing claims of value. If this value is not what the government wants to pay, it does not have to pay, but neither does it get the property. If "just compensation" is not "just" in the view of the holder of the private good, he or she can appeal to a higher court. If, at the end of the appeal process, the dollar value is not what the holder believes is "just," the property is "taken" involuntarily anyway. In the case of drug patents such an action is unnecessary and even ill advised. Too many patents "involuntarily taken" because judges were biased against inventing firms would serve as a disincentive to further invention.

To allow for this case, we propose the possibility of a market appeal. The drug could be marketed by the firm in a specific test area. The firm's motivation would be precisely the same in the test region as it would have been in the nation at large—that is, its pricing and advertising would be suitable to a profit-maximizing monopoly. The scaled-up profits would then be an indicator of the firm's true monopoly profits had it kept the patent. Because the drug would be sold only within the test region, no one would leave the area to buy the drug at a cheaper price. People entering the region to obtain the drug would bias the result, so this would have to be either prevented or accounted for when scaling up the monopoly profits.

The firm would not always resort to such a tactic because the test market profit could be less than the previous judgment, and the firm could get that lower amount after the test. Additionally, the firm would be waiting the entire test period for the award of the previous judgment. The purchasing agency would have an incentive to state the ENPVMP accurately because a history of being proved wrong in test markets would lead judges to side more often with firms.

Conclusion

The market for pharmaceuticals is clearly one in which allocative inefficiency is prevalent. Equally clear is that government attempts to reallocate are never completely efficient. The important question is whether a

government reallocation is an efficiency improvement. If the DWL associated with a pharmaceutical monopoly is as low as our conservative estimate ($3.02 billion), and thus slightly above the DWL associated with the taxes necessary to buy the patents, our proposal should be considered essentially efficiency neutral but equity positive. A DWL that remotely approaches our upper bound estimate ($29.51 billion) indicates a clear efficiency and equity improvement even with an inefficient government implementing our proposal. Getting a good estimate of the DWL associated with pharmaceutical monopoly power is therefore crucial in determining whether our proposal warrants further study. Our proposal maintains the industry motivation to invest in R&D and is neutral regarding the composition of that investment. Our estimate of the impact of policy on drug prices and on industry efficiency is imprecise, but the methodology exists for improving that estimate as well as the requisite databases. The only requirements would be time, money, and technical expertise in pharmacology and in applied economics. Perhaps it is an alternative for policy advocates who are not swayed by Scherer's (1993) leave-it-alone argument, but who agree that price controls are not the solution. An added benefit to this proposed reform is that it could be tried as a demonstration project without scrapping the entire pharmaceutical system. The government could seek a patent of interest noncoercively, make an offer sufficient that the firm would voluntarily accept the cash payment, and see if competitive behavior ensued. If substantial efficiency gains could be demonstrated, the experiment could be broadened.

Finally, we clearly demonstrate a solution to the drug-pricing problem, which, in contradistinction to all commonly mentioned alternatives to the status quo, obeys the Hippocratic imperative—at least do no harm.

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Appendix 1

Mathematically DWL is $= \frac{1}{2}\Delta P \Delta Q$, where $\Delta P = (P_1 - P_2)$ and $\Delta Q = (Q_2 - Q_1)$. Thus, finding DWL depends on knowing P_1, P_2, Q_1, and Q_2. Although we do not know values, use of the assumptions stated in the section entitled "The Degree of Allocative Inefficiency" grants us the following relations:

1) $$P_1 = 1.6P_2$$

2) $$P_1 Q_1 = P_2 Q_2$$

Those relations can be used to derive the following others:

3) $$P_1 - P_2 = .6P_2$$

4) $$Q_2 = 1.6Q_1$$

5) $$Q_2 - Q_1 = .6Q_1$$

6) $$\frac{\Delta P}{P_1} = \frac{.6P_2}{1.6P_2} = \frac{.6}{1.6}$$

7) $$\frac{\Delta P}{P_2} = \frac{.6P_2}{P_2} = .6$$

8) $$P_1 + P_2 = 1.6P_2 + P_2 = 2.6P_2$$

9) $$Q_1 + Q_2 = Q_1 + 1.6Q_1 = 2.6Q_1$$

So that

$$E_D = \frac{\frac{\Delta Q}{Q_1 + Q_2}}{\frac{\Delta P}{P_1 + P_2}}$$

$$\Rightarrow \Delta Q = \frac{\Delta P}{P_1 + P_2}(Q_1 + Q_2)E_D$$

$$\Rightarrow \text{DWL} = \frac{1}{2}\frac{\Delta P}{P_1 + P_2}(Q_1 + Q_2)E_D\Delta P$$

$$= \frac{1}{2}\frac{\Delta P}{2.6P_2}2.6Q_1.6P_2$$

$$= \frac{1}{2}\frac{\Delta P}{P_2}\frac{.6}{1.6}P_2Q_2$$

$$= \frac{1}{2} * .6 * \frac{.6}{1.6} * \text{sales}$$

$$= \$3.02 \text{ billion}$$

Appendix 2

Referring to Appendix 1 and equations 1–9, this implies the following:

1′) $$.35P_1 = P_2$$

2′) $$P_1Q_1 = P_2Q_2$$

3′) $$P_1 - P_2 = .65P_1$$

4′) $$Q_1 = .35Q_2$$

5′) $$Q_2 - Q_1 = .65Q_2$$

6′) $$\frac{\Delta P}{P_1} = .65$$

7′) $$\frac{\Delta P}{P_2} = \frac{.65P_1}{P_2} = \frac{.65P_2}{.35P_2} = \frac{.65}{.35}$$

8′) $$P_1 + P_2 = P_1 + .35P_1 = 1.35P_1$$

9′) $$Q_1 + Q_2 = .35Q_2 + Q_2 = 1.35Q_2$$

$$\text{DWL} = \frac{1}{2}\frac{\Delta P}{P_1 + P_2}(Q_1 + Q_2)E_D\Delta P$$

$$= \frac{1}{2}\frac{\Delta P}{1.35P_1}\,1.35Q_1.65P_1$$

$$= \frac{1}{2}\frac{\Delta P}{P_1}\frac{.65}{.35}P_1Q_1$$

$$= \frac{1}{2} * .65 * \frac{.65}{.35} * \text{sales}$$

$$= \$29.51 \text{ billion}$$