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# HEALTH CARE, TECHNOLOGICAL CHANGE, AND ALTRUISTIC CONSUMPTION EXTERNALITIES

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## ABSTRACT

Traditional economic analysis has proposed well known remedies to deal with consumption externalities and inefficient technological change in isolation, but lacks a general framework for addressing them jointly. We argue that the joint determination of R&D and consumption externalities is central to health care industries around the world generally, and for the pharmaceutical industry in particular. This is because technological change drives the expansion of the health care sector and altruism seems to motivate many public subsidies such as Medicaid in the US. We stress that standard remedies to the two problems in isolation are inefficient — Pigouvian corrections to consumption externalities are inefficient under technological change and standard R&D stimuli are inefficient because they focus only on consumer and producer surplus, not the altruistic surplus accruing to non-consumers. We provide illustrative calculations of the dynamic inefficiency in the level of US R&D spending due to the inability of innovators to appropriate the altruistic surplus. We find that altruistic gains amount to about a quarter of consumer surplus in the baseline scenario. Our analysis implies that total R&D could be under-provided by as much as 60 percent.



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## 1. Introduction

A long-standing literature discusses efficient methods of correcting consumption externalities through applying subsidies and taxes that align private incentives with social ones, as first recognized by Pigou (1932). However, this classic problem assumes that there is no technological change in the good that confers the external effects. An equally long-standing literature tackles the appropriate methods of stimulating innovation, *e.g.,* the analysis of the welfare effects of intellectual property (IP) regulations.[2] However, this literature traditionally posits that there are no external effects in the consumption of the good for which there is technological change.

Little, however, is understood about the principles that should govern many important allocation problems that involve *both* technological change and external consumption effects.[3] Many such allocation problems appear to occur in the health care sector, where one of the major concerns is balancing the altruistic externalities that motivate universal coverage with the technological change that such coverage may induce.[4] Indeed, in the U.S., existing evidence suggests that technological change is the key to the continued expansion of the health care sector (see *e.g.*, Newhouse 1992), close to half of which is paid for by altruistically motivated subsidy programs such as Medicaid.

One may argue that the joint altruism-R&D problem is perhaps *the* central allocation problem in health care and crucial to understanding whether the growth in health care spending

[2] Of course, there is a vast literature on the external effects of the R&D-process itself rather than on the external consumption effects of the final good, see *e.g.,* Jones and Williams (2000).

[3] See Parry (1995) for an analysis of the optimal pollution tax when the state of technology is endogenous.

[4] Many other industries, such as "research tools" industries, industries with network-, peer-group-, or herd-effects, clean energy industries, and industries in which production induces pollution, seem to involve similar issues of balancing externalities ex-post with R&D incentives ex-ante.

is efficient. Since developed nations implicitly have decided that it is intolerable to let people die or suffer when existing medical technologies can prevent it, public financing often covers such technologies. Yet, such altruistic adoption and use of new technologies should also be evaluated in terms of the technological change they induce. It seems reasonable to argue that the long-run level of health care spending is far more influenced by these important dynamic incentives than the static incentives pre-occupying current analysis by economists.

This general issue of balancing R&D and altruism is even more prominent in the sub-sector of health care made up of pharmaceuticals; the most R&D-intensive of industries and also faced with human-rights based access issues, particularly for poor nations. Indeed, the field of "global health" is often concerned with how to provide drugs to developing nations for diseases such as AIDS, malaria, or tuberculosis. This international global health issue concerns an R&D-altruism allocation problem, in many ways similar to the US domestic universal coverage issue.

Given the importance of this R&D-altruism allocation problem, we analyze whether traditional solutions to the two problems in isolation are efficient. First, we discuss the impact that R&D incentives have on the remedies aimed at solving consumption externalities such as that of altruism in health care. We argue that classic Pigouvian solutions are inappropriate under technological change. For goods with external effects, just as for those without, *ex-post* static efficiency is generally inconsistent with *ex-ante* dynamic efficiency. In particular, if Pigouvian subsidies such as Medicaid appropriately reflect the ex-post social value of health care consumption by the poor, then they lead to under-investment in R&D.

Second, we discuss the reverse problem of the impact that consumption externalities have on the appropriate stimulation of R&D. We find that standard remedies to induce the appropriate amount of technological change are inefficient as such remedies focus only on consumer- and

producer surplus, not the surplus accruing to those non-consumers affected externally. In the US health care context, rewards to innovation should not be driven only by profits or participants in, say, Medicaid but also by the altruistic surplus for those paying for this program.

To consider the efficiency losses from standard remedies, we provide illustrative calibrations for the U.S. pharmaceutical market for HIV drugs and for the U.S. health care markets more generally under the assumption that standard Pigouvian subsidies underlie public spending. The case of HIV is a particularly relevant, as consumption of those drugs is mostly financed by altruistic Medicaid subsidies, and treatment has undergone tremendous recent technological changes in the mid 1990s. Our baseline calibrations imply that altruistic gains may be as high as 25 percent of consumer surplus, on the order of $99 billion (in 2000 dollars) since the start of the HIV epidemic. For health care generally, our baseline calibrations suggest that altruistic surplus may again be nearly a quarter of consumer surplus, implying estimates of just over $1.1 trillion annually. Given existing estimates of the relationship between R&D and profits, these levels of altruism imply a potential under-investment of 23 percent for research into improved HIV therapies and 61 percent for R&D into the general health care sector as a whole.

The difficulty remains in addressing the complexities of the payer and regulator environments by choosing proper values for a handful of policy parameters; yet, while both our calibrated estimates of altruistic surplus and underinvestment in R&D vary significantly across parameter values, at a minimum, they highlight the potential large magnitudes involved. By construction, we cannot conclude that spending should increase since we posit actual subsidies (reflected by current social welfare programs) correct for the altruistic externalities. However, the results clearly emphasize the potential gains from providing more incentives for R&D by better having the surplus to non-consumers incorporated into the rewards to innovators.

The paper is related to several literatures. First, it is related to the voluminous literature on the appropriate methods of treating externalities without technological change (see e.g., Laffont, 1987 or Tirole 1988). Second, the paper also extends the classic work on the tradeoffs between direct R&D stimuli (push) and patents and prizes (pull) (see Nordhaus, 1969 and 1972; Wright, 1983; Scotchmer, 2006). Lastly, it relates to a more policy-oriented literature discussing prizes as rewards for third-world disease R&D (Kremer and Glennester, 2004).

## 2. Consumption Externalities and R&D

Consider an environment with a single potential innovation in the market.[5] We assume that a product, if developed, has external consumption effects. To fix ideas, consider the static social surplus after the technology has been developed given by:

$$W(y) = \pi(y) + s(y) + e(y) \quad (1)$$

where $\pi(y)$, $s(y)$, and $e(y)$ reflect profits, consumer surplus, and external effects induced by the output level y. The expected dynamic surplus under R&D spending R is the expected static welfare less R&D spending

$$E[W] = P(R)W - R \quad (2)$$

where P(R) is the probability of discovery that is increasing in R&D spending. Actual R&D levels are determined by the profitability of the invention once it has been discovered and thus maximize expected profits $P(R)\pi - R$.

[5] We ignore the debate over drug companies making more money off copycat drugs than with true innovations, making investment incentives too high, i.e., we assume that innovation leads to substantive surplus creation.

*2.1 Traditional remedies to correct consumption externalities*

Now consider traditional Pigouvian remedies designed to solve the externality problem in consumption. These remedies aim to maximize static welfare by aligning private consumption motives with social ones, attaining the output $y_w$ that maximizes W. However, if profits drive R&D, those subsidies and taxes would be unlikely to induce the optimal level of R&D—the level that would maximize E[W] given the social value of the innovation as the reward, when maximized at $W(y_w)$. For example, if prizes or awards are used as methods to generate profits and hence stimulate R&D, perfect competition ex-post would not correct the consumption externality. Likewise, if patents were used to generate the profits, these profits would not incorporate the surplus gained by non-consumers and hence R&D would generally be inefficient. In general, a straightforward consequence of the theory of the second-best is that a *single* instrument, such as a prize or a patent, cannot correct two sources of inefficiencies in output and R&D markets (Parry, 1995).

That fact that static efficiency through Pigouvian measures is inconsistent with dynamic efficiency is actually analogous to the case of goods with only private consumption effects. Without externalities, it is well understood that efficient competition after an innovation has been discovered leads to zero profits and hence insufficient R&D incentives, which is of course the common rationale for patents. With externalities, this has the simple but unrecognized implication that Pigouvian consumption subsidies are typically inefficient under technological change. In general, arguing for Pigouvian solutions in the presence of technological change is tantamount to arguing for competitive markets for new inventions. Both incorrectly support

static efficiency without regards to dynamic efficiency taking into account R&D incentives.[6] Pigouvian corrections may make the *total* static surplus the highest, but dynamic welfare depends on the division of surplus or the *incidence* of Pigouvian taxes, i.e., on how the distributional impact of taxation affects producers and consumers separately.

An illustration of this difference in static and dynamic efficiency is the temptation of governments to force R&D-returns down after an important innovation has been discovered and altruism dictates full adoption. For example, many observers have argued that a major barrier to R&D investments in an AIDS vaccine is that developers realize that if they are successful, governments will mandate full distribution of their products at below monopoly markups because it would be viewed inhumane not to.[7] Such policies would perhaps be efficient *ex-post* as the developer would lose less than consumers and altruists gained *ex-post*. However, this would, of course, not be dynamically efficient as no vaccine would be developed anticipating this government response.

### *2.2 Traditional remedies to stimulate R&D*

There is a large literature in economics that discusses the inefficiency in R&D decisions that occur when those who undertake the private cost of R&D, firms, do not receive the full social benefit of that investment (Arrow, 1961; Tirole, 1988; Scotchmer, 2006). Under no

[6] Note that the failure of Pigouvian solutions is not necessarily caused by the fact that patents are second-best methods of stimulating R&D. To illustrate, consider when full-price discrimination among consumers is feasible so that in the absence of externalities, the patent above would induce a first–best allocation. However, even in that case, patents are never first-best when there is an externality. This is because price discrimination does not allow the firm to capture surplus derived from external effects. This implies that under a positive externality, the monopolist always under-invests in R&D. Conversely, when the externality is negative, the producer may over-invest in R&D.

[7] A similar example is related to the recent increase in avian flu. Roche Pharmaceuticals, maker of Tamiflu (a recommended treatment for avian influenza), is facing significant pressure from several governments to allow generic distribution of its drug. While Tamiflu is still under patent, a number of Asian governments have threatened to bypass the patent and proceed with generic manufacturing if negotiated licensing fees are too high (Kanter, 2005).

externalities, the optimal prize is the present value of the social surplus: and always dominates the optimal patent.[8] This is sometimes interpreted to mean that prizes dominate patents when there are no externalities, with the implicit assumption that the organizations selecting the prizes can set them correctly to represent social surplus. This is an assumption that many times may be unwarranted. Further, like patents, prizes have negative efficiency implications since they are financed by distortionary taxes on capital and labor (an issue that, for simplicity's sake, we presently ignore).

These discussions are incomplete however - and thus the remedies implied inefficient -when there are external effects in consumption of the product. This is because only considering consumer and producer ($\pi$) surplus as potential candidates to optimally drive R&D decision leaves out the surplus of non-consumers (e). Incorporating the surplus of non-consumers as carrots or sticks for those conducting R&D is outside of traditional analysis of stimulating R&D.

This is particularly relevant for global health issues — to induce efficient R&D incentives into diseases present only in poor countries. Without externalities on rich nations, its seems efficient that a disproportionately low share of the world R&D spending on drugs is allocated to third-world diseases even though these diseases may be more prevalent and clinically more devastating. Altruism or selfishly motivated externalities make the global health issue one of allocating resources under external effects of consumption and endogenous technological change.

Therefore, a *joint* consideration of R&D and externalities further qualifies the evaluation of prizes against patents. In the presence of externalities, we have the classical result that prizes

[8] The exception is when the patent monopolists fully capture social surplus through price discrimination, in which case the optimal prize and optimal patent (infinite in length) yield the same dynamic welfare.

tend to be more favored over patents the more positive the external effects are.[9] However, although not previously recognized, this dominance of prizes under positive external effects depends crucially on how *production and distribution* take place after the prize has been awarded. The implicit assumption of the method of production and distribution under a prize is that of *free and unrestricted licensing* of the patent after the discovery, hence generating the competitive output level. If prizes induce *ex-post* efficiency without externalities, under external effects, prizes with free unrestricted licensing and a competitive level of output may be an inefficient combination. In fact, patents may dominate prizes even under positive external effects.

For example, suppose consumers are too poor to pay variable costs of production, let alone the fixed costs of R&D. This implies that the social surplus consists of the external altruistic effects of richer countries. In this case, patents would allow monopoly power that would not confer any profits, and no R&D spending would take place for any patent length. The patent holder can at most only appropriate consumer surplus, which is zero when consumers cannot pay variable costs. Hence, under free licensing patents would dominate any positive prize. This is because the R&D would be undertaken without distribution, while under a patent, the R&D would not occur. Note that this has little to do with the second-best nature of patents: the problem with patents under altruism is that the output is not sold to those willing to pay for it, that is, the rich. Appropriate R&D incentives in the global health case need to take into account that the main group that benefits in an economic sense is the rich.

[9] Note that the effect of the size of the externality on patent length is ambiguous. For instance, a larger positive externality not only raises the social value of the invention, but also increases the harm imposed by restricting its consumption through patents, making up two offsetting forces on the optimal patent life.

## 3. Calibration of R&D inefficiencies induced by Pigouvian subsidies in US health care

Given the theoretical importance of altruistic surplus for underinvestment into R&D, this section illustrates the potential size of this dynamic inefficiency for two cases; HIV drugs subsidization specifically and the entire U.S. health care economy more generally. In each instance, we show the under-investment in R&D that occurs if existing demand subsidies are viewed as Pigouvian subsidies. Our estimates should be interpreted with several caveats in mind. First, that the extent to which medical care is subsidized somehow reflects society's altruism is a strong assumption: public subsidization may proceed from other motives than simply altruism. For example, interest groups representing producers may have great impact on the extent to which demand is subsidized. Observed levels of subsidization may be construed as an upper bound measure of any underlying altruism. Second, the nature of our illustrative calibration exercise requires us to use several pieces of information from different strands of literatures. Since our calibrated estimates vary based on the assumptions made and the point-estimates used, we conduct a sensitivity analysis and display ranges of values. Ultimately, these calculations should be interpreted with caution from a quantitative standpoint but we emphasize their qualitative implications.

### *3.1 Calibrating the External Consumption Effect*

In the framework for static efficiency, suppose that for each unit sold, firms receive a per-unit subsidy $\delta$ in addition to the price consumers pay for that unit, $p(y)$.[10] The static level of social surplus can then be written as:

$$W(y, \delta) = [(p(y) + \delta)y - c(y)] + s(y) + [e(y) - \delta y] \quad (3)$$

[10] For sake of simplicity, we assume that subsidization is on a per-unit basis. Since health care is characterized by some beneficiaries receiving free care (*e.g.*, Medicaid) and others receiving no subsidization, we interpret our subsidies to be average subsidies to the entire population of consumers.

where the first term is profits, the second term consumer surplus and the third the net altruistic surplus after paying for the subsidy. For a patent monopolist, the profit-maximizing output in the presence of the subsidy is:

$$y(\delta) = \arg\max\left[(p(y) + \delta)y - c(y)\right] \tag{4}$$

*3.1.1 Parameterizing Altruism and Demand*

We specify the external consumption effect e(y) to take the following form:

$$e(y) = N\alpha \cdot s(y) \tag{5}$$

This specification captures the public-good nature of the external consumption effect. That is, each of N individuals in a society is assumed to value a fraction, α, of the consumer surplus. Moreover, altruism is a public good in the sense that each altruists' "consumption" does not preclude that by another. The net surplus enjoyed by altruists is the external consumption effect less the subsidy:

$$N \cdot [\alpha \cdot s(y) - \frac{\delta y}{N}] \tag{6}$$

Since each altruist pays only an $N^{th}$ of the per-unit subsidy, as the number of altruists increases, the cost to each of subsidizing a given level of output decreases.[11]

We assume a constant elasticity of demand $q = (\beta/p)^{\varepsilon}$, where $\varepsilon > 0$ is the elasticity of demand and β is a parameter that shifts demand outwards.

[11] The increase in N, through its effect on the subsidy, will increase output. Specifically, note that the quantity demanded by consumers depends on the price they face which, in turn, depends on the subsidy. The lower per-person cost of subsidizing a given level of output will lead to an increase in the per-unit subsidy, δ, and consequently output. While possibly even leading to on overall increase in per-person costs (δy/N), per-person costs will certainly increase above the level that would prevail if N were to increase without any compensating changes in δ and y.

*3.1.2 Optimal Pigouvian Subsidy*

The *ex-post* Pigouvian subsidy is derived by maximizing the parameterized *ex-post* welfare W(y(δ),δ) with respect to δ. Under constant returns to scale and a constant elasticity of demand, it is straightforward to show (see the Appendix) that the optimal subsidy, demand price, and supply price satisfy:

$$\begin{aligned} \delta &= \frac{c(1+N\alpha)}{\varepsilon + N\alpha} \\ p_D &= \frac{c\varepsilon}{\varepsilon + N\alpha} \\ p_S &= p_D + \delta = \frac{c(1+\varepsilon+N\alpha)}{\varepsilon + N\alpha} \end{aligned} \tag{7}$$

The optimal subsidy is increasing in both the degree of altruism, α, and the number of altruists, N. Note that the optimal subsidy in the presence of a monopolist is higher than that in perfect competition as the monopolist restricts output. Finally, note that while the prices paid by consumers and received by firms are decreasing in α and N, firm profits rise with the degree of altruism and the number of altruists.

Under the assumption that the *observed* subsidy is the *ex-post* Pigouvian solution to the problem of external consumption effects, the level of altruism will be identified through the optimality condition:

$$\frac{\delta}{p_S} = \frac{1+N\alpha}{1+N\alpha+\varepsilon} \tag{8}$$

Note that this condition implies that even in the absence of altruism, there is subsidization to correct the distortion induced by monopoly pricing.[12] It is straightforward to show that under perfect competition, the analog optimality condition is:

$$\frac{\delta^C}{p_S{}^C} = \frac{N\alpha}{N\alpha + \varepsilon} \tag{9}$$

Under perfect competition, altruism is necessary for subsidization.

*3.2 Calibration for HIV/AIDS*

Philipson and Jena (2006) estimate the consumer surplus, s, generated by the new HIV/AIDS technologies to be roughly $395 billion since the start of the epidemic nearly 25 years ago. This figure is consistent with standard values of a statistical life year around $100,000 and observed extensions in HIV life-expectancy of roughly five years when averaged across all infected cohorts. In the Appendix, we discuss the methods used to estimate the share of the price that is subsidized ($\delta/p_S$=0.5), the demand elasticity ($\varepsilon$=1.25), and the size of the non-consumer pool (N=190 million annually).[13] The demand elasticity is the most indirect parameter to be calibrated, for which we use existing patent expiration data to estimate markups of brands relative to generic competition, and hence demand elasticities—allowing this elasticity to vary within a reasonable range does not, however, alter the qualitative predictions of our calibration.[14] These quantities can then be used to identify $\alpha$, the fraction of the aggregate consumer surplus

[12] Moreover, small observed shares are consistent with a *negative* external consumption effect. Since the subsidy is designed to induce a socially optimal output, if output is observed to be below the level that would be socially optimal *in the absence of altruism*, it must be because there is a negative externality.

[13] As discussed in the Appendix, AIDS medications are largely subsidized by two programs, Medicaid and the AIDS Drug Assistance Program (ADAP), the latter administered through the Federal Ryan White CARE Program.

[14] For example, demand for HIV/AIDS drugs may be more elastic because of the natural complementarities between life-extension and the consumption of these drugs.

enjoyed by a single altruist, for either market structure, as well as the aggregate, external value to non-consumers, Nα. For the case of HIV, the aggregate value to non-consumers is a quarter of the consumer surplus (*i.e.*, Nα=0.25). For individuals infected between 1980 and 2000, this amounts to roughly $99 billion under the estimated level of consumer surplus.[15] It is important to note that the magnitude of this effect is driven by the public goods nature of the externality. To see this more clearly, note that the aggregate external consumption effect of $99 billion amortized over 20 years is simply $5 billion per year. With 190 million altruists enjoying this annually, the value of the externality amounts to $26 per altruist per year. With an estimated $3.25 billion spent on subsidies from 1980-2000 (50 percent of the $6.5 billion total HIV/AIDS drug spending), this amounts to $163 million spent *annually* by all altruists or 85 cents per altruist per year. Including these costs of subsidization leads to a *net* external consumption benefit of roughly $25 (= $26 - $.85) per altruist per year.

### *3.3 Calibration for the U.S. Health Care Sector*

Recent estimates suggest that healthcare spending in the U.S. has been quite valuable, with consumer benefits of, on average, four to five dollars for every dollar spent.[16] In general, these estimates vary significantly depending on the methods employed, the values of a statistical life year used (*e.g.*, $50,000 per life year implicit in coverage discussions in the United Kingdom

[15] An alternative specification of the externality would be $e(y) = N\alpha y$, interpreted as altruists caring about the health of others rather than their welfare (as is true when $e(y) = N\alpha \cdot s(y)$). In this case, the share of the supply price that is subsidized, $\delta/p_S$, is equal to $[cy + N\alpha y \cdot (\varepsilon-1)]/[cy \cdot (\varepsilon+1) - N\alpha y]$. If variable costs are 20 percent of sales, cy = $15 billion; meanwhile, $\delta/p_S = 0.5$ and $\varepsilon = 1.25$. Thus, the gross altruistic benefit ($N\alpha y$) is $2.5 billion. In light of the $99 billion predicted above, this result stresses the discrepancy between wrong but commonly accepted measure of welfare, namely health, and actual welfare.

[16] See *e.g.*, Cutler and McClellan (2001) and Jena and Philipson (2008). Philipson and Jena develop a methodology to link observed estimates of cost-effectiveness to surplus appropriation by producers. In their examination of over 200 health care technologies, the median ratio of gross benefits to spending was nearly 5, in line with published estimates that consumers obtain $4 - $5 of benefits for every dollar spent.

versus upwards of $200,000 per life year in the case of hedonic studies), and the health interventions considered (*e.g.*, interventions to reduce infant versus old-age mortality). On average, however, with nearly $1.98 trillion spent on healthcare in 2005 alone, this suggests an annual consumer surplus of between $5.92 and $7.89 trillions arising from healthcare consumption. Given our earlier results for HIV/AIDS, this raises the question of how altruistic surplus compares to consumer surplus for the health care sector as a whole.

We can use our framework to inform this question. First, since the *overall* market for healthcare (which includes hospital and physician services as well as drug therapies) is more competitive than that for HIV/AIDS, we begin by assuming that firms behave competitively[17] — in this case, the share of the supply price that is publicly subsidized ($\delta/p_s$) equals $N\alpha/(\varepsilon + N\alpha)$. Second, we use the fact that Medicaid and the State Children's Health Insurance Program (SCHIP) were the primary providers of subsidized health care in the U.S. as the empirical basis for altruistic spending in our model. In 2005, spending by both programs accounted for nearly 16 percent ($319 billion) of personal health care spending.

Several points are worth noting regarding our determination of which spending in the national health expenditure accounts is categorized as being altruistically motivated. First, we exclude Medicare since its benefits presumably reward contributions made by beneficiaries throughout their working lives, rather than reflect purely altruistic motives on the part of the current young. Including Medicare would simply raise the estimated level of altruism further. Second, because SCHIP has paralleled Medicaid expenditures on children, we include it as well, though 2005 expenditures by SCHIP only totaled $8.4 billion compared to $309 billion by

[17] In 2003, prescription drugs (the lion's share of spending being comprised by on-patent formulations) amounted to 11% of U.S. health care spending. The vast majority of spending was on hospitals (32%), physicians (22%), and nursing, home health, and other professional services (19%).

Medicaid.[18] Third, we include long term care for the elderly by Medicaid in the total Medicaid figure. In 2004, spending on long term care for the elderly by Medicaid comprised nearly 42 percent of total national spending on long term care (Kaiser Family Foundation, 2006). In most states, Medicaid-financing of long term care is intended to assist low-income individuals and those with specific functional impairments. In addition, in 2003, 37 percent of those receiving long term care from Medicaid were under the age of 65. Because Medicaid-financed long term care not only has specific requirements for income and disability, can be administered before the age of 65, and is therefore not applicable to the entire Medicare population, we include it in the total Medicaid figures representing altruistic spending.

Given the share of national health spending accounted for by Medicaid and SCHIP, we therefore assume that the share of the supply price that is publicly subsidized ($\delta/p_s$) equals 0.16, which implies $N\alpha = 0.19 \cdot \varepsilon$. If $\varepsilon = 1.25$, the aggregate value to non-consumers is 24 percent of consumer surplus, which is nearly identical in magnitude to our estimate for HIV/AIDS. As a benchmark case, we consider consumer surpluses arising from total health care spending that range from $5.92 to $7.89 trillions (which imply consumer benefits of four to five dollars for every dollar spent on health care). This implies an altruistic surplus of $1.41 to $1.89 trillion in 2005 alone. This also corresponds to a gross benefit to each altruist of $7,500 to $9,700 annually and a net benefit (gross benefit – cost of subsidy) of $5,900 to $8,100**.**

*3.4 Sensitivity Analysis*

These calibrated estimates of altruistic surplus are still, of course, subject to much qualification. For example, different estimates of the level of consumer surplus arising from a

[18] See CMS National Health Expenditures available online at http://www.cms.hhs.gov/nationalhealthexpenddata/.

single dollar of spending presented in the literature will affect our calculations. Note, however, that while the calibrated *level* of altruistic surplus will vary based on different estimates of consumer surplus, the *ratio* of altruistic surplus to consumer surplus identified by our model ($N\alpha = 0.19 \cdot \varepsilon$) depends only on estimates of the elasticity of demand. To the extent that the elasticity differs from the assumed value of 1.25, both the ratio and the level of calibrated surplus will of course be affected for any given level of consumer surplus. To evaluate how the calibrated level of altruistic surplus responds to various elasticities of demand and levels of consumer surplus, Table 1 presents different estimates of consumer surplus and elasticities of demand from several studies as well as the calibrated levels of altruistic surplus that those estimates imply.

**TABLE 1**: Estimates of altruistic surplus implied by several studies, by elasticity of demand

| Study | Consumer surplus from one dollar of health spending ($) | Assumed Elasticity of Demand | Altruistic Surplus ($ Billion) |
|---|---|---|---|
| Cutler & Meara (2000) | 5 | 0.25 | 470 |
| | | 1.25 | 2,351 |
| Cutler & McClellan (2001) | 3 – 4 | 0.25 | 282 – 376 |
| | | 1.25 | 1,411 – 1,881 |
| Cutler *et al*. (2006) | 0.15 – 4 | 0.25 | 14 – 376 |
| | | 1.25 | 71 – 1,881 |
| Rosen *et al*. (2007) | 1 – 3 | 0.25 | 94 – 282 |
| | | 1.25 | 470 – 1,411 |
| Cutler *et al*. (2007) | 5 – 9 | 0.25 | 470 – 846 |
| | | 1.25 | 2,351 – 4,232 |
| Jena & Philipson (2008) | 4 | 0.25 | 376 |
| | | 1.25 | 1,881 |

Notes: (1) Consumer surplus from one dollar of health spending is based on authors' calculations from each of the studies listed. Ranges of estimates within a study are often due to the population being considered. For example, in Cutler *et al*. (2006), consumer surplus of 4 dollars per dollar spent is based on spending to reduce infant mortality, while consumer surplus of 0.15 dollars per dollar spent is based on health spending by individuals aged 65 and above. Elasticity of demand of 1.25 is based on calculations shown in Appendix. A lower point estimate of 0.25 is based on estimated elasticities of demand for all health services summarized in Ringel *et al*. (2002). Altruistic surplus is based on authors' calculations.

Table 1 illustrates the broad range of calibrated altruistic surpluses that are possible for the level of public health subsidization observed in the US. Depending on the elasticity of demand and the consumer surplus arising from health spending, the associated altruistic surplus calibrated from our model may vary from $94 billion to as much as $4 trillion. For elasticities of demand that are near unity and for consumer surpluses ranging between 3 to 4 dollars for every dollar spent, the calibrated altruistic surplus is just over $1 trillion or a fifth of consumer surplus arising from total health care spending in the US. Regardless of what view one may take on the specific value for money spent on health care, the ranges of values in the literature appear consistent with a reasonable prediction that the altruistic surplus generated by such spending may be quite large.

*3.5 Implications for Underinvestment in R&D*

Given the altruistic surplus implied by our model, we present *back-of-the-envelope* calculations on the degree of underinvestment into HIV R&D due to non-appropriation of this surplus. To do so requires two pieces of information: the amount of R&D to date and the expected increase in R&D if altruistic surplus were fully appropriated. For the former, Philipson and Jena (2008) report $16 billion (discounted to 1980 and in year 2000 dollars) worth of private R&D into HIV/AIDS to date. For the latter, we use estimates from Finkelstein (2004) that a one dollar increase in the expected discounted present value of market revenue from a particular vaccine induces 5 to 6 cents worth of investment into that vaccine. While the relationship between expected revenues and innovation in the market for vaccines may not be directly comparable to either the market for HIV/AIDS, specifically, or health care, generally, to our knowledge surprisingly little *empirical* evidence exists on the link between profitability and R&D in health care. An exception is the relationship between market size and pharmaceutical

innovation documented by Acemoglu and Linn (2004). While these authors show that a 1 percent increase in potential market size is associated with a 4-6 percent increase in new molecular entities, they do not calculate how dollar revenues map into dollar R&D expenditures. Because of the paucity of empirical estimates linking expected revenues to R&D, our calculations should be interpreted not as definitive estimates of underinvestment in R&D but as ballpark figures of the general levels of underinvestment involved.

With estimates of the altruistic surplus for HIV/AIDS around $99 billion, Finkelstein's estimates imply an underinvestment in R&D of $5 billion. These figures suggest that fuller appropriation of non-consumer surplus would have increased R&D by 33 percent of R&D completed to date. Put differently, our figures suggest an underinvestment in R&D of roughly 23 percent. We can compute similar estimates for health care in general which seems all the more relevant since the U.S. Congressional Budget Office conceded in 1998 that no one knew whether current levels of pharmaceutical R&D were optimal (Outterson, 2005). In 2003, private health care R&D was nearly $35 billion. With a predicted altruistic surplus of, say, $1.1 trillion in that year alone, this implies a potential increase in R&D of $55 billion, suggesting an underinvestment into overall health R&D of nearly 61 percent. With predicted altruistic surplus ranging from $94 billion to $4 trillion, the range of underinvestment in R&D could thus vary from $4.7 billion to as much as $200 billion. While these estimates rest on several strong assumptions regarding market structure, the nature of the altruism externality, and the impact of profits on R&D, they nevertheless highlight the potential magnitude of underinvestment involved. Our calculations also clearly highlight the wide range of estimates possible.

## 4. Concluding Remarks

Although traditional economic analysis has proposed well known remedies to deal with consumption externalities and with stimulating appropriate technological change in isolation, it lacks a general framework for addressing these issues jointly. In our view, their joint presence is central to health care industries around the world where altruistically motivated subsidies are the norm and where technological change has driven the expansion of this sector. We considered the inefficiencies induced by using standard remedies to externalities and R&D stimulation. In particular, our baseline illustrative calculations suggest that the aggregate value non-consumers place on the consumption of HIV drugs in the U.S. may be as high as 25 percent of the patients' surplus, with similar estimates true for health care consumption generally. For the case of HIV/AIDS, our baseline calibrations suggest that using this surplus to stimulate investment could raise R&D by as much as 33 percent of total R&D to date.

Our simple analysis suggests several avenues of future research. While both our calibrated estimates of altruistic surplus and underinvestment in R&D appear quite large, it is important to stress that they vary within a wide range of values. Given this uncertainty and the potential magnitude of our results, perhaps the appropriate interpretation of our calibration exercise is that these empirical results must be further refined to provide accurate estimates of altruistic surplus and underinvestment in R&D.

A second area of future research is gaining a better understanding of the efficiency properties of existing policy proposals in the area of providing health care in poor countries, the concern of global health. Existing policy proposals[19] to deal with this implicit externality problem have

[19] Some proposals even demand that shareholders of innovative firms not only fund R&D to discover new treatments, but by reducing prices also cover the bill to satisfy the altruistic desires of the tax base.

been *ad hoc* in the sense that it is not clear which allocation problems the proposed solutions are optimal with respect to. Examples include Sachs *et al*. (2001) who advocate cost-based pricing financed by donor countries or Lanjouw (2002) who advocates country- and disease-specific cut-backs in IP rights.[20] There is a basic conflict between these policy proposals and an efficient provision of R&D under altruism as they reduce the benefits to innovators. The rewards to innovation should be increased rather than decreased to reflect the value to altruistic non-consumers.

Related to this problem, the provision of AIDS drugs in poor countries mimics the problem of providing drugs for rare diseases in the U.S., as well as against agents of bio-terror,[21] and it seems that international lessons can be learned from this domestic experience. With the purpose of stimulating R&D into disease classes too rare to generate R&D, the U.S. Orphan Drug Act of 1983 both reduced the cost and raised the benefit of R&D for such rare diseases.[22] If a society cares or wants to provide insurance for those who are unlucky enough to catch uncommon diseases, the social surplus will in addition to consumer surplus contain non-consumer benefits. The Orphan Drug Act may be interpreted to encourage R&D to reflect altruism, as opposed to international proposals for developing world diseases that discourage R&D in spite of such altruism. The enormous growth in drugs for rare diseases generated by the Orphan Drug Act may contain important lessons for the appropriate international policy.

[20] See also Grossman and Lai (2002) who discuss IP protection across countries.

[21] In the U.S., the legislation BioShield authorized $5.6 billion over 10 years for the government to purchase vaccines and drugs to fight anthrax, smallpox and other potential agents of bio-terror.

[22] For a description of the main features of the act, see www.fda.gov/orphan. Also see Grabowski (2003) for a related but independent discussion.

Lastly, the important issue of how world R&D should be financed across countries seems to fall under the aforementioned allocation problem. Many discussions of whether the U.S. is carrying too large a load of financing world drug R&D centers on the fact that about half of world sales are obtained in the unregulated markets of the U.S., with other price-regulated markets free-riding on the R&D investments this yields. The non-exclusivity induced by the free flow of innovations across countries, and the desire to free ride due to that non-exclusivity, entails a classic externality problem in the consumption *ex-post*, with the additional feature of involving technological change.

## Mathematical Appendix

We assume constant returns to scale (constant marginal cost c) and constant elasticity of demand, $p(q) = \beta/(q^{1/\varepsilon})$. The social welfare maximization is:

$$\underset{\delta}{Max} W(y) = \int_0^y p(q)dq - c \cdot y + N\alpha\left[\int_0^y p(q)dq - p(y) \cdot y\right] \quad \text{s.t. } y = y(\delta) \quad \text{(A1)}$$

where $y(\delta) = \arg\max_y\left[(p(y) + \delta)y - c \cdot y\right]$ describes the monopolist's optimal response to a subsidy δ. Note that p(.) is the price paid by the consumer and δ is the per-unit subsidy received by the monopolist above and beyond the price paid by the consumer. Under our assumptions on demand and production, it is straightforward to show that the monopolist-induced demand price and output satisfy:

$$p(\delta) \equiv p(y(\delta)) = \frac{(c-\delta)\varepsilon}{\varepsilon - 1}, y(\delta) = \left[\frac{\beta(\varepsilon - 1)}{(c-\delta)\varepsilon}\right]^{\varepsilon} \quad \text{(A2)}$$

We can rewrite the maximization in A1 as follows:

$$\underset{\delta}{Max} W(y(\delta)) = \int_0^{y(\delta)} p(q)dq - c \cdot y(\delta) + N\alpha\left[\int_0^{y(\delta)} p(q)dq - p(y(\delta)) \cdot y(\delta)\right] \quad \text{(A3)}$$

Recalling that p(δ) ≡ p(y(δ)), the first order condition with respect to δ is:

$$[1 + N\alpha] \cdot p(\delta) \cdot \frac{dy(\delta)}{d\delta} - [c + N\alpha \cdot p(\delta)] \cdot \frac{dy(\delta)}{d\delta} = y(\delta) \cdot N\alpha \cdot \frac{dp(\delta)}{d\delta} \quad \text{(A4)}$$

which can be simplified to:

$$[p(\delta) - c] \cdot \frac{dy(\delta)}{d\delta} = y(\delta) \cdot N\alpha \cdot \frac{dp(\delta)}{d\delta} \quad \text{(A5)}$$

Since by definition, dp(δ)/dδ can be rewritten as dp(y(δ))/dδ, by the Chain Rule, we obtain:

$$\frac{dp(\delta)}{d\delta} \equiv \frac{dp(y(\delta))}{d\delta} = \frac{dp(y(\delta))}{dy}\frac{dy(\delta)}{d\delta} \quad \text{(A6)}$$

Using A6, we can rewrite A5 as follows:

$$[p(\delta) - c] = y(\delta) \cdot N\alpha \cdot \frac{dp(y(\delta))}{dy} \qquad \text{(A7)}$$

which, under constant elasticity of demand, can be written as:

$$[p(\delta) - c] = -\frac{p(\delta) \cdot N\alpha}{\varepsilon} \qquad \text{(A8)}$$

Using the expression for p(δ) in A2, we can solve A8 to obtain the optimal subsidy δ as well as the demand price $p_D$ (recall that this is equal to p(.)) and supply price $p_S$ (note, $p_S = p_D + \delta$).

$$\delta = \frac{c(1+N\alpha)}{\varepsilon + N\alpha}, p_D = \frac{c\varepsilon}{\varepsilon + N\alpha}, p_S = \frac{c(1+\varepsilon+N\alpha)}{\varepsilon + N\alpha} \qquad \text{(A9)}$$

Using A9, we obtain an expression relating the share of total expenditure on drugs that is publicly subsidized ($\delta/p_S$) to the level of altruism and the elasticity of demand. Specifically,

$$\frac{\delta}{p_S} = \frac{1+N\alpha}{1+N\alpha+\varepsilon} \qquad \text{(A10)}$$

Finally, we can calculate the ratio of profits to social welfare as follows:

$$\frac{\pi}{W} = \frac{\left[\frac{c}{\varepsilon + N\alpha}\right] \cdot y(\delta)}{\int_0^{y(\delta)} p(q)dq - c \cdot y(\delta) + N\alpha\left[\int_0^{y(\delta)} p(q)dq - p(\delta) \cdot y(\delta)\right]}$$

$$= \frac{\left[\frac{c}{\varepsilon + N\alpha}\right] \cdot y(\delta)}{\frac{\varepsilon\beta}{\varepsilon - 1} \cdot (y(\delta))^{\frac{\varepsilon-1}{\varepsilon}} - c \cdot y(\delta) + N\alpha\left[\frac{\varepsilon\beta}{\varepsilon - 1} \cdot (y(\delta))^{\frac{\varepsilon-1}{\varepsilon}} - \frac{c\varepsilon}{\varepsilon + N\alpha} \cdot y(\delta)\right]}$$

$$= \frac{\left[\frac{c}{\varepsilon + N\alpha}\right]}{\frac{\varepsilon\beta}{\varepsilon - 1} \cdot (y(\delta))^{\frac{-1}{\varepsilon}} - c + N\alpha\left[\frac{\varepsilon\beta}{\varepsilon - 1} \cdot (y(\delta))^{\frac{-1}{\varepsilon}} - \frac{c\varepsilon}{\varepsilon + N\alpha}\right]}$$

$$= \frac{\left[\frac{c}{\varepsilon + N\alpha}\right]}{\frac{\varepsilon\beta}{\varepsilon - 1} \cdot \frac{p_D}{\beta} - c + N\alpha\left[\frac{\varepsilon\beta}{\varepsilon - 1} \cdot \frac{p_D}{\beta} - \frac{c\varepsilon}{\varepsilon + N\alpha}\right]}$$

$$= \frac{\left[\frac{c}{\varepsilon + N\alpha}\right]}{\frac{\varepsilon}{\varepsilon - 1} \cdot \frac{c\varepsilon}{(\varepsilon + N\alpha)} - c + N\alpha\left[\frac{\varepsilon}{\varepsilon - 1} \cdot \frac{c\varepsilon}{(\varepsilon + N\alpha)} - \frac{c\varepsilon}{\varepsilon + N\alpha}\right]}$$

$$= \frac{1}{\frac{\varepsilon^2}{\varepsilon - 1} - (\varepsilon + N\alpha) + N\alpha\left[\frac{\varepsilon^2}{\varepsilon - 1} - \varepsilon\right]}$$

$$= \frac{(\varepsilon - 1)}{\varepsilon^2 - (\varepsilon + N\alpha)(\varepsilon - 1) + N\alpha\left[\varepsilon^2 - \varepsilon(\varepsilon - 1)\right]}$$

$$= \frac{(\varepsilon - 1)}{\varepsilon + N\alpha} \qquad \text{(A11)}$$

Note that the share of social surplus appropriated to producers is positive since the monopolist operates in the elastic portion of the demand curve ($\varepsilon > 1$).

## Data Appendix

This Data Appendix describes how the following are obtained: 1) the share of the price of HIV/AIDS drugs that is publicly subsidized, 2) the elasticity of demand, and 3) the number of non-consumers (*i.e.*, altruists). These, along with consumer surplus measures obtained from Philipson and Jena (2006), are used to calibrate our model.

### Consumer Surplus from HIV/AIDS Drugs

Using the methodology developed in Becker, Philipson, and Soares (2005), Philipson and Jena (2006) estimate the value of increased survival attributable to HIV/AIDS drugs. For each cohort infected with HIV, the authors estimate the aggregate value of improved survival relative to a benchmark in which no treatment was available. They repeat this for each new set of cases, cohort by cohort, since the start of the epidemic and aggregate up. This delivers the gross value to consumers of improved survival induced by HIV/AIDS therapies. The consumer surplus is obtained by netting out total spending, which is described below.

### Financing of HIV/AIDS Drugs

The majority of public spending on HIV/AIDS drugs is administered through two sources, Medicaid and the AIDS Drug Assistance Program (ADAP). To be eligible for Medicaid, individuals must be low-income and in one of several mandated categories. Many AIDS patients qualify for Medicaid by being recipients of Supplemental Security Income (one of the mandated categories). These individuals are both low-income and disabled (Kates and Wilson, 2004).[23]

The AIDS Drug Assistance Program began shortly after the introduction of AZT in 1987. Since 1990, ADAP has been part of the Ryan White CARE Program, the third largest federal source for care of HIV/AIDS patients. Since 1996, Congress has specifically designated funds for ADAP through the CARE program. ADAP is a payer of last resort for prescription medications needed by those without insurance or other means to finance drug treatment. In 2001 alone, an estimated 135,000 individuals received assistance from ADAP.

Figure 1 presents estimates of national spending on HIV/AIDS drugs broken down by public and private payers. The estimates for total spending are from IMS Health.[24] Public spending is approximated by the sum of Medicaid and ADAP expenditures. The Medicaid estimates include both federal and state contributions and were calculated from the Medicaid State Drug Utilization Data using National Drug Codes (NDC) for all anti-retrovirals introduced since 1987.[25] Medicaid expenditure on HIV/AIDS drugs is unavailable prior to the last quarter of 1991—this is likely because Medicaid began its Prescription Drug Rebate Program (for all drugs, not just anti-retrovirals) only in 1990.[26] Data on ADAP expenditures are unavailable prior to

[23] Eligibility for SSI requires an income below 74 percent of the Federal Poverty Line (FPL). In 2004, this amounted to an annual income of nearly $7,000.

[24] See Lichtenberg (2005).

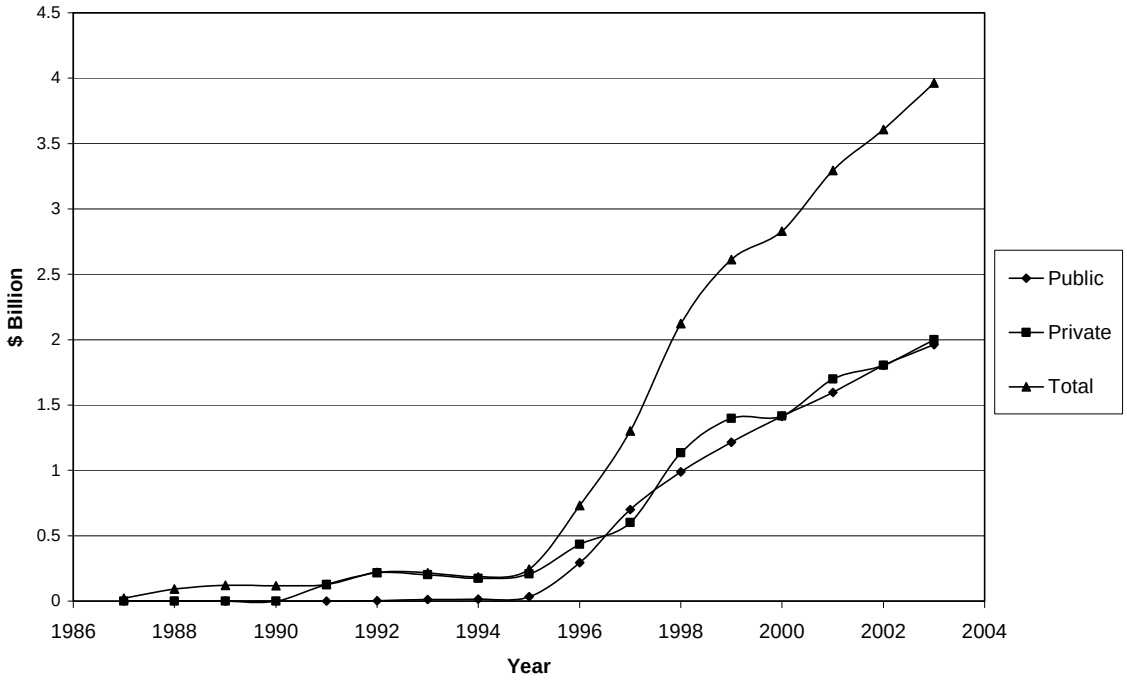
[25] http://www.cms.hhs.gov/medicaid/drugs/drug5.asp

[26] Key Milestones in CMS Programs, http://www.cms.hhs.gov/about/history/milestones.asp

1996, though it was informally covering some individuals through the Ryan White CARE Program prior to that.[27]

Since 1995, total spending has increased from $250 million to almost $4 billion, largely due to increased spending on protease inhibitors and nucleoside reverse transcriptase inhibitors. Figure 1 also demonstrates the large share of total spending on HIV/AIDS drugs financed by public sources, nearly 50 percent from 1996 onwards. Based on the above data, we parameterize $\delta/p_S$ to equal 0.5.

**Figure 1: National Spending on HIV/AIDS Drugs**




## Elasticity of Demand and the Number of Altruists

We use the familiar monopolist mark-up condition, $(p-c)/p = 1/\varepsilon$ to provide an estimate of the elasticity of demand for HIV/AIDS drugs.[28] Using estimates from the literature on the prices of generic drugs relative to their branded counterparts, we assume variable costs to be no more than 20 percent of sales.[29] With constant returns to scale in variable costs, marginal cost is constant and equal to variable cost. This suggests, $(p-c)/p = .8$ or alternatively that $\varepsilon = 1.25$.

We assume the number of altruists financing HIV drug consumption, N, to equal 190 million annually. This is the average number of adults alive in the U.S. each year from 1980 to 2000. While this figure does not reflect the annual number of tax-payers in the U.S., it does partly

[27] Through communication with Kaiser Family Foundation.

[28] Since the monopolist only produces in the elastic portion of the demand curve, $\varepsilon$ is bounded from below by unity.

[29] See Caves, Whinston, and Hurwitz, (1991). We use the price of generic drugs as an upper bound of the marginal costs of production. The authors estimate that with 20 generic competitors, the ratio of prices between generic and brand drugs is roughly 20 percent.

capture non-working individuals in households who also benefit from the external consumption effect. Note that our choice of N will not alter the *aggregate* value altruists place on consumer surplus—it simply affects our estimates of the per-altruist external consumption benefit.

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