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ABSTRACT

In his Labor Day address, President Biden stated that the U.S. "has the highest drug prices in the world, and there is no reason for it." For new branded drugs, the first part of that statement is supported by a recent RAND Report (Mulcahy et. al. 2021) which found U.S. average prices are 2.3 times those present in both the 32 OECD countries overall and in the UK separately. In this research, we consider the second part of that statement, and identify the economic factors that suggest some "reasons for it."

Viewing pharmaceutical markets through the lens of the theories of global public goods and alliances, as developed by Olson and Zeckhauser (1966), we explain the observed pricing differences along with their implications the for the global supply of innovative new drugs. Similar views were advanced in two U.S. government reports (CEA 2018, 2020), and also by Goldman and Lakdawala (2018). We develop these ideas further and implement them empirically.

A commonly held theory presumes that drug companies in the U.S set prices for patented drugs at profit- maximizing levels that fund and incentivize substantial research and development efforts. In contrast, in the rest of the world (ROW), national authorities set prices minimally above marginal costs of production, allowing few revenues remaining to support R&D (CEA Report 2018; Blumenthal 2018; Hooper and Henderson 2022). The ROW countries are then considered to be fully free riding on U.S. research efforts. We examine this argument both theoretically and empirically, and find it wanting.

We apply global public good theory to examine the pricing of branded drugs. To this end, we describe the optimal global contribution, as supported by the Lindahl pricing model, and show theoretically that existing independently determined contributions and thereby aggregate R&D levels are likely sub-optimal. Then we implement the model by calculating the contribution to the global public good as represented by short-term profits or quasi-rents received from sales of all branded drugs. These calculations are derived from pricing data contained in the RAND Report along with two market-based estimates of marginal costs.

We find that, while ROW contributions are less than those found in the United States, they are more than minimal, and do not approach zero for most countries. When we regress these positive contributions on a country's size of GDP along with various controls, we find that GDP size alone is a powerful determinant of national contributions. It remains economically and statistically significant without regard to the controls introduced. In addition, we estimate how large are the contributions of ROW countries to the global public good. We offer reasons why US pharmaceutical prices and contributions per capita are nevertheless higher than those found in all ROW countries. We also suggest actions aimed to promote R&D efforts that are closer to the global optimum.

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I Introduction

In his Labor Day address, President Biden stated that the US "has the highest drug prices in the world, and there is no reason for it" (Biden 2022)[1]. The first part of President Biden's statement, as applied to branded pharmaceuticals is undoubtedly correct. Indeed, as reported in the recent RAND Report, (Mulcahy et. al. 2021, p. 49), US prices for "Brand Name Originator Drugs" are more than twice the average found in 32 OECD developed countries, even after adjusting US prices for rebates and discounts.[2] While the RAND Report does not offer explanations for these differences, that is our purpose here. Our object is to describe the economic forces that have led US branded prices, and therefore contributions to R&D incentives, to be much higher than those in the rest of the developed world (ROW).

For this purpose, we turn to the economic theory of public or collective goods. By accounting for the new information embodied in branded drugs, we derive implications from this theory for international pharmaceutical prices and quantities. To be sure, we are not the first to consider drug prices through this lens. See the US Council of Economic Advisors (CEA) Reports (2018, 2019), Egan and Philipson (2018), and Goldman and Lakdawalla (2018). However, the analyses presented there were not fully developed, and our object here is to fill that void. We develop this concept further and implement it empirically.

A commonly-held explanation for how the prices of patented drugs are determined in the United States assumes that prices are set during periods of patent protection at monopoly profit-maximizing levels. In contrast, national authorities in ROW countries typically set prices

[1] Similar statements were made by former President Trump (Imbert 2019).

[2] However, for generic drugs, prices are lower in the US than in the other countries at only 84 % of the prices for the rest of the OECD countries. Further, generic drugs have a much larger share in the US than in other developed countries (Mulcahy et. al. 2021, p. 49).

impacted by budgetary concerns with little concern for the sunk costs of pharmaceutical research and development. Instead, they normally presume that the advanced medications pharmaceutical R&D and the advanced medications that result from pharmaceutical R&D are entirely exogenous. Although, US policy discussions of drug pricing issues commonly include their likely effects on the incentives for innovation (Filson 2012; Goldman and Lakdawalla (2018); Lackdawalla; 2018, US Congressional Budget Office (CBO) 2020), that is less common in discussions of pricing in other countries. Indeed, there appear fewer concerns expressed by ROW authorities about the future supply of innovative pharmaceuticals.

An important explanation for the exceptional status of US policy is the explicit legislative mandate directed at the branded pharmaceutical industry that is embodied in the Hatch-Waxman Act of 1984. That law has been judicially interpreted as follows

> "The Act emerged from Congress' efforts to balance two conflicting policy objectives: to induce name-brand pharmaceutical firms to make the investments necessary to research and develop new drug products, while simultaneously enabling competitors to bring cheaper generic copies of those drugs to market" (*Abbott v Young*, 1990).

The higher prices charged for branded pharmaceuticals during their effective patent lives are a direct result of US law that is designed intentionally to incentivize pharmaceutical innovation.

II Promoting Pharmaceutical Innovation

Discovering new ideas to treat or prevent disease, along with establishing the safety and efficacy of products grounded on those ideas is an expensive proposition. Current R&D costs per new pharmaceutical agent are estimated at more than $3 billion (DiMasi 2015). Furthermore, it has also been recognized that "marketing and innovation investments are

complementary" (Lakadawalla 2018, p. 438); and that extensive product advertising to disseminate information is required for the widespread use of innovative pharmaceuticals. On this account, promotional efforts are typically greatest at the start of a product's life-cycle and then declines continually through the life of the product, finally ending prior to patent expiration. (Lakdawalla and Philipson 2012, p. 169-171, Ellison and Ellison 2007, p. 33, Bhattacharya and Vogt, 2003, Wieringa 2012). In effect, both R&D and marketing efforts together comprise the process by which new drugs are discovered and become widely used. Marketing is part of the process that takes a new drug idea from concept to large scale use in a health system. R&D spending and marketing spending are thereby complements.

Despite the high revenues received by drug companies, there is evidence that, on average, the resulting health benefits are large, and also they are higher for more highly priced drugs. . A recent study by Buxbaum and colleagues (2020), investigated the aggregate effects of pharmaceuticals on the substantial increase in US life expectancy between 1990 and 2015. They found that pharmaceuticals were second only to Public Health Measures in importance, and contributed 35% of the overall gain. See also Lichtenberg (2005, 2007) who reported similar overall conclusions, and also Philipson and Jena (2006) who focused on the substantial health benefits gained from AIDS drugs. See also Frech, Pauly, Comanor, Martinez (2022) who report that expected therapeutic gains from new pharmaceuticals, on average, exceed their incremental costs.

The scientific information created by drug company R&D efforts, or purchased from independent biotech companies, is embodied in the medicines offered for sale. However, since the cost of creating the embodied scientific knowledge is largely borne before a single unit of the drug can be sold, these expenditures represent sunk costs that support all units sold. As with all

sunk costs, R&D investments are recovered from differences between the prices received and direct production and distribution costs; effectively by the difference between price and short-run marginal costs.

Because past R&D costs are already paid, they do not directly influence the prices charged for existing drugs. Instead, the determination of R&D outlays depends on the anticipated connection between the incremental profits to be recovered from future new drugs and the long-run incremental cost of inventing, testing, obtaining approval and initially promoting new pharmaceuticals. Hence, expected markups of prices over marginal production and distribution costs serve to incentivize R&D efforts designed to develop advanced pharmaceutical agents.

In this setting, drug company revenues exceeding direct production and distribution costs, represent an "investment in innovation" (Berndt et al., 2015, p. 251). Indeed, there is substantial economic support for connections among drug prices, R&D outlays and pharmaceutical innovation. See in particular Scherer's report of the direct connection between overall profit margins and R&D spending (2001). In addition, Civon and Malony (2009) find that current drug prices are an important determinant of R&D spending (2009), and Giaccotto, Santerre and Vernon (2005) find that prices charged for current drugs are an important determinant of the number of prospective new drugs in the R&D pipeline (2005). Furthermore, in an early study, Comanor provided statistical evidence of the association between R&D efforts and the number of new pharmaceuticals where each is weighted by its sales in the first two years following introduction (1965). More recently, Frank and Hannick find the correlation between R&D spending and new drug approvals to be "only moderate positive at 0.58" (2022, p. 2). Unlike the earlier study, their simple count of the number of new drugs fails to account for the inherent

heterogeneity across realized benefits from new drugs that makes a count of products an unreliable index of pharmaceutical innovation.

In the analysis to follow, we assume that company revenues exceeding production and distribution costs need not represent excess returns over costs but rather are payments that incentivize their investment in efforts to gain pharmaceutical knowledge, data and information which is then embodied in innovative drugs. These payments also support the promotion and rapid diffusion of innovative pharmaceuticals that directly expands their returns and contributes to health improvements. As such, these revenues are appropriately designated as "quasi-rents" used to support essential sunk costs rather than monopoly profits. Indeed, in the absence of barriers to innovation and entry, returns on investment in new drug development would earn a competitive rate of return.[3]

III Pharmaceutical Information as a Global Public Good

Although drugs themselves are usually private goods, the information embodied in them, is the essential public good we consider here. In fact, the classic example of a public good is information, both scientific and practical (Stiglitz 1999; Cruzet, Eberly, Eisfeldt and Papanikolaou 2022, p. 3). While often costly to produce, the use of new information by one person or entity does not limit the amounts available for others. Indeed, this presence of "non-rivalry" is the essential feature of all public goods: their value is not diminished by one person's use but remains fully available for others. In addition, information once created, is both readily

[3] Consistent with free entry driving long-run profits towards zero, Grabowski and colleagues reported that the aggregate rate of return from new drugs is close to the cost of capital. They estimated these returns at 11.5% as compared to the estimated cost of capital of 11.0%. (Grabowski, Vernon and DiMasi, 2002).

disseminated and difficult to control. This potential non-excludability factor is an important element of many public goods.

The public good concept is particularly applicable to information embodied in the therapeutic properties of new pharmaceuticals.[4] While international patent protection is commonly used to exclude rivals from using the information during the life of the patent, this information is readily used by generic producers upon patent expiration. At that point, the informational public good is no longer excludable. Only temporarily does patent law makes this public good excludable, and even then, perhaps not perfectly. The temporary excludability permits the knowledge originator to capture some of its social benefit as "quasi-rents."[5]

Were pharmaceuticals sold in a single world-wide market under a single legal and regulatory system, policy issues would then be straight-forward, at least conceptually. Manufacturers with appropriate temporary patent protection would then have the ability to charge prices that incentivize both discovery and production costs. And since the former are inherently risky, with most prospective pharmaceuticals never approved or sold, the expected profits for successful drugs would need to be sufficient to include the costs of unsuccessful projects. In principle, a single body could then decide how to regulate patent exclusivity to incentivize the preferred supply of industry R&D, considering both the welfare benefits of new knowledge and the welfare loss due to monopoly pricing of the products supplied, as well as cost of R&D, marketing/information, production, and physical distribution.

[4] One might think that direct governmental production might be superior to private production of innovative ideas with patent protection. But, the incentives for *applied* R&D are generally considered to be superior for private firms, so that form of organization is dominant in drug R&D across the world. See Stiglitz (1999, pp. 312-314) and Jones (2022, p. 2228).

[5] This concept is termed "appropriability" in the economic literature on innovation. Appropriability is generally low for innovations, especially for new drugs (Frech, Pauly, Comanor and Martinez 2022; Philipson and Jena 2006.

These issues, however, are far more complicated when prospective sales are divided into separate national markets with different national authorities that have little concern for, or even knowledge of, global welfare. Individual countries design or accept institutional arrangements through which prices are determined. Following a detailed review of international health care systems, Rice aptly points out that "nearly all of the countries either set country-level pharmaceutical prices or engage in explicit negotiations with manufacturers" through a central authority. However, he continues, "none of these activities are carried out by the US federal government." (Rice 2022, p. 209).

Although US prices are set through negotiations by drug companies with multiple public and private payers, that is not the case in ROW countries where government officials typically exercise significant buying power. It is thus commonly suggested that, in ROW countries, national authorities set prices that just slightly exceed the marginal cost of production, with minimal concern for the sunk costs of R&D. Underlying this judgment is the view that drug companies make R&D investment decisions based entirely on expected revenues in the US market (Hooper and Henderson 2022). As a result, it is frequently presumed that, from the ROW decision-making vantage point, pharmaceutical R&D spending and the advanced medications that result are entirely exogenous, and countries can completely free ride on that spending if they so choose.

This view of ROW pricing is widespread. See for example the first CEA Report, which states that "foreign governments can insist on a price" just above marginal cost of production (2018 p. 14). Writers for the Commonwealth Fund similarly claim that in negotiation with drug companies, national authorities are "willing to walk away" if they are charged more than they consider appropriate (Blumenthal 2018). Similarly, in a recent editorial, Hooper and Henderson

assert that the ROW countries "free ride" by using coercion to compel drug firm to accept prices just above the marginal cost of production under the threat of refusing to buy any of the company's products, and firms accept this low price because "some money is better than no money" (2022). These accounts, however, do not fit easily with common theoretical models used to derive the supply of public goods, nor are they consistent with models in which drug companies with sole-source products bargain with ROW countries.

In what follows, we specify alternatives to the full free-riding model, and employ economic data to determine which account seems most applicable to the actual pattern of pharmaceutical prices in both the US and ROW countries. Although the drugs themselves are private goods, the information embodied in them is the essential public good emphasized here. And it is this knowledge and information that is generated from the net product revenues received. To be sure, it is the expected returns from new product introductions that are relevant for discovery outlays, and not those received from prior ones. However, expectations of future revenues are determined in large part by typical returns received from current introductions.

We employ the economic structure outlined above to model the global public good provided through pharmaceutical innovation. For the reasons outlined above, we do not use the number of new drugs to represent pharmaceutical innovation. Instead, we let the pharmaceutical quasi-rents received in each OECD country represent its national contribution to the global public good, and then consider how optimal national decision-making impacts the global optimum. We then subject our theoretical results to empirical testing.

IV Economic Models Considered

In the analysis to follow, we employ game theoretic and bargaining concepts to explain and interpret international price differences that determine national contributions to the global public good resulting from industry R&D; which in turn affects the global availability of new advanced pharmaceuticals. We first suggest a basic Nash non-cooperative or independent-adjustment model in which all OECD countries are presumed to make optimal decisions for their own constituents. That would imply negotiating the lowest possible unit price consistent with adequate and timely supply of appropriate volumes of new effective drugs.

Despite its very different pricing structure, the United States has also adopted policies designed to further its own purposes. While it has currently chosen a market-like process, the US could instead have followed the path used elsewhere and require price negotiations between drug companies and government officials. Indeed, in recent legislation, the US has moved in that direction (Omeokwe and Hughes 2020). The US could also vary, and in fact has varied, the length and breadth of regulatory and patent-based exclusivity along with other policies that will affect the profitability of drug innovation. Through such actions, the US has effectively determined its contribution to the global public good.[6]

We also consider two alternate models to the one proposed above. In the first of them, ROW authorities are concerned not only with setting low prices but also account for the prospective effects on industry research and development.[7] Often, this approach takes the form of "value-based pricing" by which government authorities reward drug companies for

[6] For a good discussion of the "balancing act" that governments in general do regarding the levels and duration of exclusivity and therefore the share of the social value of an innovation received by the innovator, see (Stiglitz 1999, pp. 311-313).

[7] For more discussion of this type of Nash model, see Egan and Philipson (2013).

introducing higher quality products at prices that may exceed the marginal cost of production. For example, Ekelund and Phersson (2003) provide relevant data on this model for Sweden.

A second alternate model suggests itself. Suppose drug companies do not accept the low prices proposed by ROW authorities for new innovative drugs but instead require higher prices for a timely supply, or even for any willingness to supply their new drugs at all. On this point, there is evidence that low ROW government-imposed prices have led to a "drug lag" in which drug entry dates are postponed for some years following the earlier US entry (Danzon and Furukawa, 2008). Furthermore, US approved drugs are "refused public reimbursement or not recognized for public reimbursement" in Australia, Canada and the UK. (Pham, Le, Draves and Seoane-Vazuez 2023, p. E.1) Hence there is a bargaining process whose outcome may well be a price in excess of MC. This process has been modeled with the Nash bargaining model, leading to intermediate prices where the consumer surplus resulting from the new drug is shared between the innovator and consumers (CBO 2019, p.8).

V. The Global Optimum Quantity of the R&D Public Good and the Lindahl Model

We now define a first-best optimum for the global economy in order to contrast it with projected outcomes from the various models, and also what is empirically observed. To this end, we recount Samuelson's theoretical characterization of the optimal supply of a public good (1954; 1955).

Assume provisionally that all prospective drugs have a uniform expected R&D cost prior to launch (including the cost of failure) of *$R* per drug. Assume also that officials from each OECD country set policies to align with the median preferences of their country's citizenry. And let the average per capita value of the health benefits resulting from prospective drug *j* be V_j. In

that case, Samuelson's optimal decision rule would be to set prices such that the country's population times V_i just equals or exceeds *$R* after accounting for the R&D costs of all drugs provided. That judgment embodies Samuelson's optimality condition determined by the "sum of marginal rates of substitution" (1955, p. 353). In other words, the optimal quantity of the public good is achieved when marginal cost equals the sum of the relevant demand prices.

A means to achieve global optimality would be to employ the Lindahl, or marginal benefit, model. That model presumes that each country pays an amount towards the public good just equal to its relative valuations, V_i's, at the optimal quantity. In other words, all countries who benefit from the public good at the margin pay their demand price for the quantity supplied. The resulting equilibrium then satisfies the Samuelson condition for optimality.

While global optimality for aggregate R&D outlays can therefore be defined, it is not readily achieved in the presence of multiple independent countries. Even if there were agreement on the principle of value-based contributions, each government is strongly incentivized to understate its valuation to reduce its contribution without appreciably affecting the availability to its citizens of new, advanced pharmaceuticals. That motivation is especially strong in small countries. As there is no higher authority to enforce Lindahl behavior, each country's commitment to serve its population's interests may well lead to the under-provision of this global public good. While Lindahl equilibrium quantities are optimal and provide a useful standard, that model by itself is not incentive-compatible, and therefore is implausible as an explanation of what actually occurs.

VI. Applying the Theory of Public Goods to New Pharmaceuticals

As presumed earlier, advanced pharmaceuticals lead to improved health status for all countries' citizenry. This strong commonality of interest suggests the possibility of an implicit, if not explicit, alliance among OECD nations designed to foster the development and introduction of beneficial new drugs. On this basis, we turn to the economic theory of alliances for insight as to how member nations would be expected to conduct their affairs.

At the start of their discussion, Olson and Zeckhauser acknowledge that, "it may well be that most alliances are never embodied in any formal agreement" (Olson and Zeckhauser 1966b, p.273). They emphasize that it is not the presence of a signed agreement that signifies an alliance but rather the reality that all members benefit from whatever communal efforts everyone is willing to take.

The Olson/Zeckhauser paper focused on the global public good of national defense against aggression. It posits two important features of most alliances. The first is that "individuals (here countries) acting independently do not have an incentive to provide optimal amounts of such (collective) goods" (Olson and Zeckhauser 1966b, p. 267), a proposition that was later elaborated by Pauly (1970) and Sandler and Cauley (1975). Suboptimal provision is expected even when "individual members have an incentive to make significant sacrifices to obtain the collective good" (Olson and Zeckhauser 1966b, p. 268). In effect, where all countries pursue only their own national interests, the likely outcome will generally fall short of the optimal provision of the communal good.

They also recognized a second important feature of many alliances: "there will also be a tendency for the 'larger' members – those that place a higher absolute value on the public good – to bear a disproportionate share of the burden" (Olson and Zeckhauser 1966b, p. 268). In effect,

the larger members who may be more invested in the alliance will commonly bear the larger per capita costs.

In the analysis that follows, we apply this theoretical apparatus to the pricing of new branded pharmaceuticals. The critical factor here is that the quasi-rents, or net revenues, expected from established prices reflect a country's contribution to the global public good of pharmaceutical innovation. This approach offers a very different lens through which to view drug industry net revenues than those who believe that pharmaceutical profits are a negative factor that should be limited. See for example DeAngelis (2016) and Anderson (2014). Viewing expected returns as contributions that incentivize the production of an important global public good places these returns in a very different light.

In the discussion below, we avoid discussing the diverse political issues pertaining to the prices paid and the revenues received in individual countries. Instead, we presume that all measures taken depend entirely on the country's underlying economic conditions. By adopting this approach, we adopt the presumption that "states internationally behave like private actors, motivated by national self-interest," which is an approach commonly pursued in both the economic and political science literatures on alliances and international cooperation (Kaul, Grunberg and Stern 1999, p. 15). Our analysis, therefore, presumes that the relevant authorities in each country select a pharmaceutical pricing strategy that maximizes their countries' social welfare including the discovery and development of innovative pharmaceuticals, but do not consider any benefits that accrue elsewhere.[8]

[8] Similar presumptions underlie works by Eagan and Philipson (2013) and the US CEA (2018; 2020).

VII. The Nash Non-cooperative Model

While the economics developed below is similar to that offered originally by Olson and Zeckhauser, we employ the more formal approach of Bergstrom, Blume and Varian (1986). We model the volume of the relevant public good as the aggregate number of homogeneous new beneficial drugs (here assumed to have the same marginal health benefits per capita), and also identical R&D costs. While these presumptions permit a more tractable analysis, they do not detract from the insights gained.

Consider a world of n countries, with each one potentially purchasing pharmaceuticals at prices above the marginal cost of production and distribution. Net revenues then incentivize the global public good of pharmaceutical innovation. In such circumstances, each country contributes to the quasi-rents that motivate industry efforts. Let there be diminishing returns to an increased number of new drugs resulting from declining marginal valuations of the life-years gained. In that case, the total number of new advanced drugs developed, Q, is supported by the total contributions of n countries divided by the (assumed uniform) cost of the R&D sufficient to produce one additional drug, indicated by R.

In contrast, x_i is the consumption of an aggregate, countrywide private good in country i. Each country is modeled as having a well-behaved utility function for two goods reflecting both its own consumption of the private good and also the global aggregate of innovative new drugs that results from the public good supplied by international drug companies. There is therefore no country subscript on the public good, Q, for countries that consume the new, more efficacious pharmaceuticals.

In these circumstances, each country's officials are presumed to maximize their nation's utility:

$$u_i(x_i, Q)$$

where each country is endowed with wealth, w_i, that is divided between the private composite good x_i, and its contribution to the public good defined above. Each country then decides how much, if any, it will contribute towards the global public good that produces and distributes future new drugs, aggregated over all drugs currently consumed. Throughout, each country recognizes that its contributions subtract from its consumption of all other goods.

Finally, let each county comply with the conventional Nash behavioral assumption that its utility-maximizing contribution will not affect the contributions of any other country. In effect, each country's contribution is then its best response to the contributions of all other countries.

Under these conditions, we can define a Nash equilibrium of contributions to the global public good that incentivizing future drug development indicated by the vector of contributions by all countries: $(R_i^*), i = 1,2 \ldots n$. In equilibrium, for each country i, R_i is the solution to the following:

$$\text{Max } U_i\ (x_i, Q)$$

subject to the budget constraint:

$$w_i = x_i + R_i,$$

and also, the underlying production function for transforming contributions into the public good. Note that each country's decisions are impacted by the current level of contributions (if any) by all other countries toward global R&D. As a result, the sum of world-wide revenues exceeding

short-run marginal costs determines the aggregate returns from pharmaceutical innovation and thereby the expected value of improved pharmaceuticals.

In a Nash model with an interior equilibrium, more than one country would willingly contribute payment toward the global public good. This outcome is consistent with the analysis of Egan and Philipson (2013). However, a Nash corner equilibrium is also possible where one country voluntarily contributes a large amount to the global public good to which no other country contributes anything. That result is consistent with both the CEA Reports and the Hooper/Henderson editorial. In that scenario, each ROW country pays just enough for its drugs consumed to cover the marginal cost of production and distribution, while high US prices contributes so large an amount that other countries' valuation of additional new drugs falls short of *R*. Other ROW countries therefore contribute nothing to the global public good despite benefiting from its availability. It is also possible for some countries to be at a corner solution and contribute little or nothing to the public good while others reach an interior solution and contribute a significant amount.

Note that in the Nash/Alliances model, contributions to support the public good are strategic substitutes. Whenever one country contributes more, each other countriy contributes less, but instead spends more on its own country's consumption of available private goods. The analysis of a simplified two-country version of this model is therefore analogous to the two-firm Cournot model. If the reaction functions do not cross, a corner solution occurs and one country makes the entire contribution to the public good. But instead, if the reaction functions intersect, and so long as the public good is a normal good, an equilibrium with more than one county contributing to the public good exists and is stable (Cornes, Hartley and Sandler 1999). An interior equilibrium outcome is portrayed in Figure 1. In this graph the US and aggregate ROW

reaction functions cross at the Nash non-cooperative equilibrium where the US contribution is *US** and the ROW contribution is *ROW**.

In Figures 2, 3 and 4, we offer simplified versions of three possible outcomes. In each figure, the horizontal axis is the private good consumed by individual country *i* while the vertical axis is the public good supported by all countries, *Q*. Line segment *AD* represents the overall budget constraint faced by an individual country. However, the amount Q^*_{-i} on each graph indicates the aggregate amount that all other countries (not *i*) contribute to the global public good such that under the Nash behavioral presumption, the operative portion of the budget constraint for any single country is limited to the segment *AB*. In these graphs, the contribution of all other countries is held constant at Q^*_{-i}; while they differ according to the country's demand conditions for the global public good. The segment BD is not available since contributions to the public good cannot be negative.

Represented in the three figures are three types of countries, described with three different utility functions. Figure 2) denotes a high-demand country that contributes a great deal to the public good, C_i^*; Figure 3) describes a medium-demand country that contributes a small positive amount, while Figure 4) represents a low-demand country that contributes nothing. Its best outcome is thereby represented as a corner solution. As noted above, it is theoretically possible that only one country contributes to the public good while the outcomes of all others are depicted as corner solutions.

VIII. Alternate Pricing Behavior and Policy Options

As suggested above, Nash outcomes leading to interior solutions may exist where some or all ROW countries contribute substantially to the global public good, even though the contribute less than required for a Lindahl optimum. Particularly since US contributions are so substantial, some large ROW countries may prefer the interior solution represented in Figure 3, while some small ROW countries may be expected to choose the corner solution represented in Figure 4, thus completely free riding on the contributions of larger countries.

Because contributions depend on prices negotiated with drug companies, bilateral bargaining between ROW countries and drug companies may arise. In that case, each side will have something to lose if an agreement is not reached. While companies would lose the prospective returns from lack of an agreement, the countries would lose their timely access to advanced new drugs. In that case, one might expect an outcome in which prices exceed marginal cost, but fall short of monopoly levels.

Another alternative is represented by the widespread belief that "value-based pricing" is the appropriate structure through which regulatory prices should be set.[9] In this paradigm, ROW countries would choose to reward successful high-value innovation by paying higher prices, – without regard to production costs. While such prices may incentivize R&D efforts to some extent, they appear less consequential than the market-based incentives found in the United States. Another feature of this approach is that it is derived as an independent concept rather than from the country's national interests; and as such without regard to its underlying utility function

[9] See the arguments advanced in (Neumann 2021).

Despite the incentive problems inherent in the Lindahl model of public goods, inferior outcomes could be avoided through international agreement. Efforts to create multi-country agreements involving higher revenues received in ROW countries while keeping US generated revenues at current levels would be a step in that direction. That approach would resemble international trade agreements that convert the underlying circumstances from a non-cooperative to a cooperative game. We interpret the two CEA reports on this subject (2018; 2020) as advocating this approach.

IX. Evidence on How Drug Prices Determine Contributions for the Global Public Good

Because pharmaceutical prices that exceed marginal production and distribution costs incentivize and guide the production of the global public good of pharmaceutical innovation, we seek evidence on the prices paid for new branded pharmaceuticals. Fortunately, useful price indices for 33 OECD countries in 2018 have recently become available which can be used for this purpose. See the data provided in the recent RAND Report (Mulcahy et. al. 2021). That study covers all OECD countries that are the main potential source of contributions to this global public good, represented here by pharmaceutical spending minus the marginal costs of production and distribution.

A country's contribution to the global public good of pharmaceutical innovation is given by the proportion of the sales revenue in that country that exceeds *MC* times

$$the\ i^{th} Country's\ Contribution = \frac{(P_i - MC)}{P_i} S_i$$

where P_i is price index of innovative drugs in country i, S_i is the associated innovative drug revenues, and *MC* is the estimated marginal cost assumed the same in all countries. That assumption of identical marginal cost values is clearly an abstraction because the *MC* includes both manufacture and distribution costs; and it is likely that distribution costs are lower in low-wage countries. The price indices and revenues refer to brand-name originator drugs which embody the advanced knowledge created by prior R&D outlays.

The relative prices from the RAND Report need be transformed from their reported values which are US prices relative to OECD prices, and thereby provide price premiums in percentage terms:

$$US\ Price\ Premium\ for\ the\ i^{th} Country = \frac{P_{US}}{P_i}(100)$$

For our purposes, we transform those price indices into proportions of the corresponding US prices. To this end, we invert the published indices for the innovative drugs, and multiply by 100 so that the price index for the i^{th} country is:

$$P_i = \frac{1}{US\ Price\ Premium\ for\ the\ i^{th} Country}(100)$$

For example, the price index for brand-name originator drugs for the UK is calculated as 43% or 0.43, which indicates the UK price index is 43% of the US index for the corresponding branded drugs. Coincidentally, the value for the total of all ROW countries is also 43% of the US index.

To calculate the sales revenue for branded originator drug using the RAND report data. (p. 19, col 1), we multiply reported total sales by the proportion of total sales due to brand-name originator drugs (p. 20, col 1):

$$S_i = (TS_i)(BS_i)$$

where TS_i = Total Sales, and BS_i = Brand Share. In addition, both population (POP) and real 2018 GDP values in 2018 US dollars are available in the Penn World Tables (Feenstra, Inklaar and Timmer 2015).

Returning to the UK example, we find total brand name sales of

$$S_{UK} = (\$23.B)(0.71) = \$16.83B.$$

At this point, we require estimates of marginal costs. For this purpose, we use two alternate, market-based approaches. The first is simply to derive *MC* values from the RAND Report data on price indices. Since firms will not profitably set prices below marginal costs, a possible approach is to use the prices index of the lowest paying country, Turkey, as providing a rough estimate of marginal cost. This simple procedure provides a value of 14.2% of the US price index. This estimate, however, may be too low; perhaps influenced by either a very different basket of drugs or lower distribution costs in this low-income country.

A second approach rests on estimates of pharmaceutical marginal costs available in the economic literature and summarized in a recent CEA Report. The CEA estimates *MC* as 16% of *list* price on average for branded drugs in the US, ignoring rebates and discounts (CEA 2018, p.24). That estimate is based on data from studies that also calculate the average US price declines resulting from generic entry. (Caves et. al 1992; Grabowski and Vernon 1992; Brendt and Aitken 2011). The fundamental concept employed here is that prices approach marginal

costs when substantial generic entry occurs. The CEA reviewed these studies and reported that the average estimated price decline following large-scale generic entry over the studies reviewed is 84%, implying average marginal costs of 16% of the earlier *list* price (CEA 2018, p. 24). This estimate, however, must be adjusted for the average US rebate of 33 percent for branded drugs, (Mulcahy et. al. 2021, p. 25). In that case, we estimate an average *MC* value of 24% of net US prices, or 0.24.[10]

In the analysis below, we use both *MC* estimates to calculate alternate national contributions to the global public good. While the there are some quantitative differences in our calculations, the results are qualitatively the same. The basic results and insights are not sensitive to the specific value of *MC* employed.

A. Calculating Contribution to the Public Good

1. *MC* from the RAND Report

Using the RAND estimate of MC at 14.2% of the US price, each country's contribution to the global public good can be determined as:

$$\frac{[P_i - (P_{US})(0.142)]}{P_i}(TS_i)(BS_i)$$

An example is the UK contribution to the global public good, which is determined as

$$\frac{0.43 - 0.142}{0.43}(\$23.7B)(0.71) = \$11.23B$$

[10] Note that using an *MC* value of 0.24 will lead to negative contributions for three lower-income countries: Turkey, Greece and Estonia so their logarithms do not exist. In sensitivity tests, dropping or including the observations for these three countries in a linear version of this model made almost no difference. See below.

Alternatively, for the US, we have:

$$\frac{[P_{US} - (P_{US})(0.142)]}{P_{US}} S_{US}$$

which provides a US contribution of:

$$\frac{1.0 - 0.142}{1.0} (\$464.0)(0.82) = \$326.44B$$

As reported here, the UK contribution is about 3.5% of the US contribution. As the UK population is about 20% of the US population, the UK contribution per capita would then be about 18% of the US per capita contribution.

2. *MC* from the Literature

As noted above, the CEA estimate of marginal cost is 24% of the US index. Using that larger estimate, we calculate somewhat different estimates for each country's contribution to the global public good. For the UK, we find:

$$\frac{0.43 - 0.24}{0.43} (\$23.7B)(0.71) = \$7.44B$$

In contrast, for the US we have:

$$\frac{1.0 - 0.24}{1.0} (\$464.0)(0.82) = \$289.16B$$

The higher estimate of *MC* leads to a larger reduction in the UK's calculated contribution relative to the US so the UK percentage is lower. With this estimate of *MC*, the UK's percentage

would then equal about 2.6% of the US contribution, and about 13% of the US contribution per capita.

The calculated contributions of all OECD countries are provided in Table 3. While the US is much the largest contributor to the relevant global public good, many OECD countries contribute substantially. The US alone is not the sole source of incentives for world-wide pharmaceutical innovation.

B. The Implied US Percentage of Global Contribution

1. *MC* from the RAND Report

As noted above, the US contribution is: $326.44B. In contrast, the ROW contribution (proxied by the rest of the OECD) is:

$$\frac{0.43 - 0.142}{0.43}(\$331.2)(0.73) = \$164.28B$$

These calculations indicate that the US contribution is approximately 66 percent of the total. That figure is broadly consistent with prior estimates of between 64 and 78% (Goldman and Lakdawalla 2018), and also with a study (Chen, Pauly, Comanor and Frech forthcoming) using a different approach.

2. *MC* from the Literature

Using this MC estimate, the US contribution is $289.16B. In contrast, the ROW contribution is:

$$\frac{0.43 - 0.24}{0.43}(\$331B)(0.73) = 106.83B$$

In this case, the US contribution represents about 73% of the total.

3. National Contributions

See Tables 1 and 2 for descriptive statistics of this data set as well as correlation coefficients across the relevant variables. In Table 3, we report all national contributions derived from both MC estimates, along with other data. The most striking feature of these data is the position of the United States. Indeed, when MC is estimated at 24% of the US price index, the US accounts for 72% of the OECD total; while when MC is estimated at 14.2%, its share is slightly lower at 67%. Japan and Germany, also make substantially above-average contributions, although far smaller than that of the United States. On a per capita basis as well, the US predominance is evident with contributions of $884 and $998 respectively. In the presence of such disparities, the US may be the only OECD country consistent with Figure 2.

In contrast, there are a number of countries with minimal contributions per capita. See for example the values reported for Chile, Mexico and Turkey. In such instances, the corner solution depicted in Figure 4 appears more likely with minimal contributions made to the global public good. For most OECD countries, however, it appears that the intermediate position suggested in Figure 3 is more representative as they make substantial contributions to the global public good.

C. Free-Riding by ROW Countries is Only Partial

As indicated in Table 3, various OECD countries make substantial contributions to the global public good of pharmaceutical innovation. They provide amounts of between $115 billion and $164 billion per year, which represents between 27% and 33% of total global support for the public good.

The average ROW country pays between 1.8 and 3 times *MC*, depending on the estimate of *MC* employed. However, there appears to be considerable variation among the ROW countries in our sample. The notion that other advanced countries are all paying near *MC*, and thus largely free-riding, is not supported by these data. It is therefore not the case that the US alone incentivizes pharmaceutical innovation

To be sure, a substantial amount of free riding by ROW countries appears to remain. While US annual per capita contributions approach $1000 annually, the next higher countries are Switzerland at between $264 and $354, Japan at between $227and $318, and Canada between $209 and $286. All other OECD countries contributed even less per capita to the global public good.

X. Determinants of Contributions: Empirical Estimates

A. Basic Approach and Variable Definitions

To determine national support levels for this global public good, we estimate single-equation OLS models explaining differences in national contributions among the OECD countries included in the RAND report. As emphasized in prior economic studies of investment in drug innovation (Acemoglu and Linn 2004), our primary explanatory variable is the size the economy, measured simply by national GDP.[11]

The underlying theoretical construct is that a country's economic size determines the total value of the public good consumed by its citizens, both because larger populations imply more people to benefit from a new drug and also because higher GDP per capita is associated with

[11] For more on measures of country size for global public good problems, see (Shresta and Feehan 2002/2003). Specifications with GDP per capita and population entered separately had far lower explanatory power than using total GDP alone because entering these variables separately imposes an inappropriate functional form.

higher monetary values of improved health. Indeed, the demand for this public good, as derived from the demand for health, has generally been found to have a positive income elasticity of nearly 1.0 for non-US countries (Hammitt and Robinson, 2011; Viscusi and Masterman 2017).

In addition, there is the prospect that nations with large pharmaceutical industries will permit higher prices and thereby contribute more to the global public good in response presumably to pressures from its national companies. In that case, a country's contribution might exceed those from countries with minimal drug industries. We account for this possibility by sequentially adding indicator variables for the ROW countries with substantial drug industries: the US, Japan, Germany and Switzerland.

As before, we employ alternate market-based estimates of *MC*: 14.2% and 24% of the US price index in calculating estimates of a nation's contribution to the global public good. These alternatives lead to different dependent variables of a country's pharmaceutical sales above marginal cost. As before, they are derived from the RAND data as follows:

$$S_i = (TS_i)(BS_i)$$

where the first term in this expression is the pharmaceutical total sales volume and the second is the proportion of those sales of branded originator drugs. In addition, the 2018 population (*POP*) and real GDP values in 2018 US dollars are drawn from the Penn World Table (Feenstra, Inklaar and Timmer 2015).

B. Specifications

The baseline specification is a two-variable linear regression equation:

$$C_i = \alpha + \beta_1 GDP_i + \varepsilon_i$$

although we also estimate equations with indicator variables for the US, Japan, Germany and Switzerland. The equations are estimated in natural logs for the continuous variables so the estimated coefficients represent elasticities.

C. Empirical Findings

1. Main Results for Country GDP Size

A country's GDP explains a large share of its contribution to the global public good. See Table 4 where *MC* is estimated at 14.2% of the US price index. The simple linear regression that includes ln GDP alone explains 89% of the variation in contributions across countries, and is highly significant at better than the 1% level, with a t-statistic of 16. See Table 4, Column 1. Furthermore, the size effect as reflected by its GDP is quantitatively large with an estimated point elasticity of 1.23. In addition, the arc elasticity indicating the effect of a doubling of GDP is even higher at 1.45, due to the non-linear property of a logarithmic equation.[12] In this case, this estimated equation projects that, on average, doubling GDP would lead to increased contributions to the Global Public Good by 145%.

This estimated equation also provides a direct test of the hypothesis that in collective efforts, there is a tendency of the "small 'exploiting' the large," that is commonly referred to as the "exploitation" hypothesis. In contrast, if public good contributions were made

[12] Doubling GDP raises lnGDP by 0.7, so that lnCont increases by (0.7)(1.23)=0.86. Taking the antilog, this raises Cont by 1.45 or 145%.

proportionately to a country's GDP, with a regression coefficient close to 1.0, the hypothesis would not be supported.

The findings presented above describe a strong, economically significant size effect such that national contributions to the global public good are estimated to increase more than proportionately relative to increases in a country's GDP. Note also that the estimated elasticity coefficient in Table 4, Column (1) is significantly greater than unity, where the null hypothesis is an estimated coefficient of unity. In this case, the relevant t-statistic is 2.95 (0.23/0.078), which is statistically significant at the 1.0% level in a two tailed test. These findings are consistent with the "exploitation" hypothesis.

To separate a US effect from a more generalized size effect, we introduce a US indicator variable, as reported in Table 4, Column 2. In that case, the US variable is highly statistically and economically significant but the generalized size effect also remains statistically and economically significantly different from zero. While the estimated GDP coefficient is slightly lower than before at 1.17 rather than 1.23, it remains both statistically and economically significant, with a t-statistic of 14. This result suggests that the underlying size-contribution relationship is not dependent only on the US observation. Despite its large size and contribution, the US effect does not determine the underlying size effect. Instead, the size relationship predicted by the Nash interior equilibrium model continues to explain a large degree of variation in global public good contributions among non-US OECD countries.

In addition, the "exploitation" hypothesis is again supported although the evidence is somewhat weaker with increased variability. The comparable test statistic based on the estimates provided in Table 4, Column 2 is now 2.0 (0.17/0.085) which is statistically significant at the 10.0% level and nearly statistically significant at the 5% level. Even after accounting for the

distinct US effect, the "exploitation" hypothesis that larger countries bear a disproportionately large share of contributions to the global public good is supported by the statistical evidence.

We next add indicator variables for three other countries with notable pharmaceutical industries: Japan, Germany and Switzerland. These variables are all positive and, except for Germany, statistically significant at the 5% level. This finding suggests that having a domestic drug industry affects a nation's calculus of the country-level benefits conveyed by this global public good. Since some quasi-rents are captured by firms in these countries, there are national benefits from encouraging larger contributions. Most important, adding those additional indicator variables slightly reduces the estimated size effect (from 1.17 to 1.13), but even at its smaller value, it remains economically and statistically significantly different from zero.. However, as expected precision declines with the full set of indicators, partly because the dummies reduce the effective variation in the data. The GDP coefficient is no longer statistically significantly greater than unity. There is thus strong evidence supporting the "exploitation" hypothesis for the full sample of countries, although the evidence gets weaker once one accounts for the two or three largest countries—because presumably there is less of a systematic relationship between GDP and contribution in that case. Empirical support for the "exploitation" hypothesis among the remaining countries is thereby less powerful when both the US and Japanese markets are separately indicated. Furthermore, this support remains despite the presence of reference pricing and trans-shipments that tend to suppress cross-country variation among OECD countries. (Schweitzer and Comanor 2011; Danzon 2018; Salant 2022; Maini and Passamoli 2023)).

The prior discussion rests on findings associated with the smaller estimate of *MC*, and we now consider these issues with estimates based on our higher estimate of *MC* at 24% of the US price index. See the empirical results reported in Table 5, Column 1. Qualitatively similar, these

results show slightly larger size effects, with an estimated elasticity of contribution with respect to size of about 4% higher. Again, this equation fits the data well. Furthermore, the effects of the indicator variables are roughly similar to those found earlier, especially for the US and Japan. Overall, these estimates are somewhat less precise than those reported earlier. The results are robust to alternative assumptions on *MC*.

Again, the lowest estimates for the generalized size effect appears in the most complete equation that includes indicator variables for all four countries. In this case, with higher presumed marginal costs, the estimated size effects are slightly larger than before.

D. Sensitivity Tests

To check for possible data and functional form issues, we performed various sensitivity tests. First, we estimated the regression equations in linear rather than logarithmic form for the continuous variables. The results were similar to the earlier findings. Next, we now included observations for Turkey, Greece and Estonia that had been discarded from the logarithmic version because of zero or negative contributions. This variant made almost no difference to the GDP estimated coefficients.

We also relaxed our assumption that the instruments chosen to affect the contribution to the global pubic good were completely endogenous with respect to the country's intended contribution. We did that by entering variables for the out-of-pocket cost of health care and for the threshold value of the cost-effectiveness required by national authorities or insurance companies to accept a drug for payment. Neither was significant at the 10% level, though the CE threshold was close to statistical significance in one specification. Most important, the size

effect was little affected by the presence of these variables. Thus, the basic results appear highly robust to alternative specifications.

XI. Discussion

In his classic treatment of public goods, Olson emphasized that "the satisfaction of any common interest means that a public or collective good has been provided for that group" (Olson 1971, p. 15). Since the development of new, therapeutically advanced medicines are valued in all countries, efforts to discover and develop them clearly represent a global public good. In this study, we explore the implications of explicitly acknowledging that pharmaceutical research and development has major benefits globally.

Olson draws two significant implications from his analysis when applied to small groups of beneficiaries, in this case the OECD countries. His first conclusion is that "there is a tendency in small groups towards a sub-optimal provision of collective goods." Furthermore, "the larger the number in the group, … the more serious the sub-optimality will be" (Olson 1971, p. 28). Applied to pharmaceutical innovation, this conclusion translates to a recognition that the greater the number of smaller countries benefiting from R&D outlays, the more the aggregate underinvestment in these efforts, and the lower the level of pharmaceutical innovation.

The second of Olson's implications is even more striking. "The member with the largest [share of prospective benefits] will bear a disproportionate share of the burden…. [such that] there is a systematic tendency for 'exploitation' of the great by the small" (Olson, 1971, p. 29). Applied to the global public good of pharmaceutical R&D, a greater burden would then be shouldered by the largest member of the group. Since support for this public good is determined by the quasi-rents received from branded pharmaceutical sales, which are far greater in the

United States than elsewhere, Olson's analysis thereby predicts the higher revenues and prices paid for branded, originator pharmaceuticals in the United States than elsewhere.

In this study, we consider spending on pharmaceuticals above the levels required to cover marginal production and distribution costs through a lens that emphasizes their support of the global public good of pharmaceutical R&D. In this construct, these outlays represent an investment in pharmaceutical innovation that delivers large worldwide social returns. These revenues are considered as "quasi-rents" rather than monopoly profits in that they incentivize and guide essential sunk costs. Indeed, we consider this manner of funding such costly efforts as the only practical way to accomplish that result.

When seen in this light, the conclusions stated above are particularly relevant. There is clearly a world-wide interest in supporting the development of new therapeutically valuable medications; and this commonality of interest provides the basis for this global public good. Furthermore, as widely acknowledged, such goods are likely to be under-supplied.

In our analysis, we define a Lindahl equilibrium that represents worldwide optimality, but also consider the factors that make its achievement unlikely. Most important among them is the presence of independent and self-interested behavior that leads support for this public good to fall short of the worldwide ideal level. However, where officials at ROW countries base their buying prices on perceived product values rather than on cost-minimization objectives, or where drug companies can bargain effectively for prices exceeding marginal costs, a country's contributions to the global public good is expanded, and there are greater prospects for world-wide public health benefits. For these reasons, US officials could raise these issues at international negotiations and advocate for higher prices than presently set in high-income ROW

countries. A multi-country agreement in this direction would represent a serious effort to support improved world health.

Economic forces also lead the largest countries to assume a more-than-proportional share of the burden needed to produce a communal good. Consistent with that judgment is that US prices of branded innovative pharmaceuticals are much higher than those found elsewhere, which thereby provides greater support for global pharmaceutical R&D. That conclusion is reached both in country aggregates and by per capita expenditures.

A direct implication of our finding of low ROW support per capita for this global public good is that "free riding" exists where countries pay less than their implicit valuation of any new medications discovered. But the observed free riding is not complete. We also find that leading ROW countries contribute a significant share of the total funding. On this account, we can reject the frequent assertion that all ROW countries pay only marginal costs and thereby provide minimal support for the public good.

That buyers are willing to pay more for comparable pharmaceuticals in the United States than elsewhere can be explained by significant structural differences. In earlier research, we reported that average launch prices of US branded pharmaceuticals lie below $40,000 per Quality Adjusted Life Year (QALY) gained on average from new pharmaceutical (Frech, Pauly, Comanor and Martinez 2022).[13] That estimate should be contrasted with available evidence on revealed consumer preferences in the United States for additional QALYs. What studies of consumer and labor decisions describe is that US public "willingness to pay" amounts for the prospect of an additional QALY exceeds $200,000 (Viscusi, 2020). The difference between

[13] The estimated $40,000 upper limit is inflated for two reasons: First, it is based on list prices, not prices net of rebates and discounts. The discounts and rebates are large, estimated to average to 33% of list prices (Mulcahy, et. al. 2020). Second, it is only available temporarily, during the remaining life of the patent.

these two broad estimates provides a conservative indication of the median price increase that a fully-informed US public would willingly bear rather than let an effective drug be unavailable. In effect, this difference of at least $160,000 per QALY suggests that even the US is on average underpaying its support of this global public good. (Frech, Pauly, Comanor and Martinez 2022). If the US contribution is low, the ROW countries' even lower contribution exacerbates the problem. This conclusion does not preclude the prospect that some branded drugs are overpriced in the US, but it suggests that on average the US prices do not fully incentivize valuable R&D efforts.

To be sure, US prices largely result from negotiations between payers and producers (as buyers and sellers), and paid for the most part collectively, either though taxation or insurance premiums. As a result, they ignore the societal distributive effects associated with high consumer prices paid by uninsured or underinsured patients. For such consumers, policy measures are needed to offset the effects on low income consumers that may occur. However, the need for such measures is not a reason to negate the worldwide societal benefits gained from enhanced pharmaceutical innovation.

That US prices charged for branded, originator drugs are higher than those found in other ROW countries is undisputable. These higher prices provide the leading source of support for the global public good depicted here. The connection between these prices and enhanced R&D efforts is embodied in an industrial structure specifically created by the 1984 Hatch-Waxman Act, and which has been recognized in judicial decisions (*Abbott v Young*, 1990).

Because this global public good is likely to be undersupplied on a world-wide basis, policies that limit the extent of ROW free-riding would move towards a more economically efficient allocation.

REFERENCES

Abbott v Young, 920 F.2d 984; (1990).

Anderson, Richard, "Pharmacy industry get high on fat profits," BBC (Nov. 6, 2014) www.bbc.com/news/business-28212223

Antos, Joseph and James C. Capretta, "Prescription Drug Pricing: An Overview of the Legal, Regulatory and Market Environment," American Enterprise Institute, Economic Perspectives (July 2018).

Bergstrom, Theodore, Lawrence Blume and Hal Varian, "On the Private Provision of Public Goods, *Journal of Public Economics* 29 (1986): 25-49.

Berndt, Ernst and Murray Aitken, 2011. "Brand Loyalty, Generic Entry and Price Competition in Pharmaceuticals in the Quarter Century after the 1984 Waxman-Hatch Legislation," *International Journal of the Economics of Business*, 18(2) (Nov. 2011): 177-201.

Bhattacharya, Jayanta, and William B. Vogt. "A Simple Model of Pharmaceutical Price Dynamics." *The Journal of Law & Economics* 46, (2) (October 2003): 599–626.

Biden, Joseph, Labor Day Address, September 5, 2022.

Blumenthal, David, "It's the Monopolies, Stupid" Commonwealth Fund Blog, (May 24, 2018).

Buxbaum, Jason D., Michael E. Chernew, A. Mark Fendrick, and David M. Cutler, "Contributions of Public Health, Pharmaceuticals, and other Medical Care to US Life Expectancy Changes 1990-2015," *Health* Affairs, 39(9) (2020): 1546–1556.

Caves, Richard D., Michael D. Whinston, Mark A. Hurwitz, Ariel Pakes and Peter Temin, "Patent Expiration, Entry, and Competition in the U.S. Pharmaceutical Industry," *Brookings Papers on Economic Activity. Microeconomics*, Vol. 1991 (1991): 1-66.

Chen, Angela, Mark V. Pauly, William S. Comanor and H.E. Frech, III, "The Global Distribution of New Drug R&D Costs: Does the Rest of the World Free Ride," (forthcoming).

Civan, Abdulkadir and Michael T. Maloney, "The Effect of Price on Pharmaceutical R&D," *B.E. Journal of Economic Analysis & Policy* 9(1) (2009): Article 15.

Comanor, William S., "Research and Technical Change in the Pharmaceutical Industry," *Review of Economics and Statistics*, 47, (May 1965) 182-190.

Comanor, William S., Stuart O. Schweitzer, Jon Riddle and Frederic Schoenberg, "Value Based Pricing in the US and the UK: Does Centralized Cost Effectiveness Analysis Matter?" *Review of Industrial Organization* 52 (June 2018: 589-602.

Cruzet, Nicholas, Janice C. Eberly, Andrea L. Eisfeldt and Dimitris Papaniknoau, "The Economics of Intangible Capital," *Journal of Economic Perspectives* 36(3) (Summer 2022): 29-52.

Danzon, Patricia M., "Differential Pricing of Pharmaceuticals: Theory, Evidence and emerging Issues," *PharmacoEconomics* (36) (2018):1395-1405.

Danzon, Patricia M., Richard Wang and Liang Wang, "The Impact of Price Regulation on the Launch Delay of New Drugs – Evidence from Twenty-Five Major Markets in the 1990s," *Health Economics*, 14(3) (2005): 269-292

Danzon, Patricia M., Andrew W. Mulcahy and Adrian K. Towse, "Pharmaceutical Pricing in Emerging Markets: Effects of Income, Competition and Procurement," *Health Economics* 24 (2015): 238–252.

DeAngelis, Catherine D, "Big Pharma Profits and the Public Loses," *Milbank Quarterly* 94(1) (March 2016): 30-33.

DiMasi, Joseph A., "Innovation in the Pharmaceutical Industry: New Estimates of R&D Costs," UCLA Seminar on Pharmaceutical Economics and Policy, December 3, 2015.

Egan, Mark and Tomas J. Philipson, "International Health Economics, National Bureau of Economic Research, Working Paper No. 19280 (August 2013).

Ellison, Glenn and Sara Fisher Ellison, "Strategic Entry Deterrence and the Behavior of Pharmaceutical Incumbents Prior to Patent Expiration," NBER Working Paper 13069, April 2007.

Filson, Darren, "A Markov-perfect equilibrium model of the impacts of price controls on the performance of the pharmaceutical industry," *RAND Journal of Economics* 43(1) (Spring 2012): 110-138.

Frank, Richard G. and Kathleen Hannick, "5 things to understand about pharmaceutical R&D," USC-Shaefer-Brookings on Health Policy (June 2, 2022), https://www.brookings.edu/blog/usc-brookings-schaeffer-on-health-policy/2022/06/02/five-things-to-understand-about-pharmaceutical-rd/

Frech, H. E., III, Mark V. Pauly, William S. Comanor and Joseph R. Martinez, "Costs and Benefits of Branded Drugs: Insights from Cost-Effectiveness Research," *Journal of Benefit-Cost Analysis* 13(2) (2022): 166–181.

Feenstra, Robert C., Robert Inklaar and Marcel P. Timmer (2015), "The Next Generation of the Penn World Table," *American Economic Review* 105(10) (2015): 3150-3182. Data available for download at www.ggdc.net/pwt

Giaccotto, Carmelo, Rexford E. Santerre and John A. Vernon, "Drug Prices and Research and Development Investment Behavior in the Pharmaceutical Industry," *Journal of Law & Economics* 48(1) (April 2005):195-214.

Goldman, Dana and Darius Lakdawalla, "The Global Burden of Medical Innovation," Brookings Institution (Jan. 30, 2018).

Grabowski, Henry G., and John M. Vernon. "Brand Loyalty, Entry, and Price Competition in Pharmaceuticals after the 1984 Drug Act," *Journal of Law & Economics* 35(2) (Oct. 1992): 331–50.

Hemmitt, James K. and Lisa A. Robinson, "The Income Elasticity of the Value per Statistical Life: Transferring Estimates between High and Low Income Populations," *Journal of Benefit-Cost Analysis*, 8(2) (2011).

Hooper, Charles A. and David Henderson, "Expensive Prescription Drugs Are a Bargain," *Wall Street Journal* (November 14, 2022).

Imbert, Fred. "Trump appeals for lower drug prices: '(This is wrong, unfair and together we can stop it.'" CNBC (February 5 2019), https://www.cnbc.com/2019/02/05/trump-calls-for-lower-drug-prices-at-the-state-of-the-union.html.

Jones, Charles I., "Taxing Top Incomes in a World of Ideas," *Journal of Political Economy* 130(9) (September 2022): 2227-2274.

Kaul, Inge, Isabelle Grunberg and Mark A. Stern Stiglitz, Joseph D. "Defining Global Public Goods," in *Global Public Goods*, ed. by Inge Kaul, Isabelle Grunberg and Mark A. Stern, Oxford: (1999): 2-19.

Lakdawalla, Darius N., "The Economics of the Pharmaceutical Industry," *Journal of Economic Literature* 56(2) (June 2018): 397–449.

Lakdawalla, Darius N. and Tomas Philipson, "Does Intellectual Property Restrict Output? an Analysis of Pharmaceutical Markets," *Journal of Law and Economics* 55 (1) February 2012, pp. 151-187.

Lichtenberg, Frank R, "Pharmaceutical Knowledge-Capital Accumulation and Longevity," in *Measuring Capital in the New Economy*, ed. by Carol Corrado, John Halitwanger and Dan Sichel NBER, University of Chicago Press (2005): 237-274.

Lichtenberg, Frank R. "Benefits and Costs of Newer Drugs: An Update," *Managerial and Decision Economics*, 28(4/5) (June – Aug. 2007): 485-490.

Mas-Collel, Andre, Michael D. Whinston and Jerry Green, *Microeconomic Theory*, Oxford University Press (1995).

Maini, Luca. And Fabio Passamoli, "Reference Pricing as a Deterrent to Entry: Evidence from the European Pharmaceutical Market," *American Economic Journal: Microeconomics*, 15(2) (2023): 345-383.

Mulcahy, Andrew W., Christopher Whaley, Mahlet G. Tebeka, Daniel Schwam, Nathaniel Edenfield and Alejandro U. Becerra-Ornelas, *International Prescription Drug Price Comparisons: Current Empirical Estimates and Comparisons with Previous Studies*, RAND Research Report (2021).

Neumann, Peter, Joshua T. Cohen, Daniel A. Ollendorf, *The Right Price*, Oxford University Press, 2021.

Olson, Mancur, *The Logic of Collective Action*, Harvard University Press, 1965, 1971.

Olson, Mancur Jr. and Richard Zeckhauser, *An Economic Theory of Alliances*, Rand Corp., memorandum RM-4297-ISA (Oct. 1966a).

Olson, Mancur Jr. and Richard Zeckhauser, "An Economic Theory of Alliances," *Review of Economics and Statistics*, 48(3) (Aug., 1966b): 266-279.

Omeokwe, Amara and Siobhan Hughes, "What's in the Democrats Bill on Climate, Health and Tax Policy," *Wall Street Journal* (Aug. 12, 2022).

Pecorino, Paul, "Should the US allow prescription drug reimports from Canada?" *Journal of Health Economics* 21(4) (2002): 699–708.

Pham, Catherine, Kim Le, Masha Draves and Enrique Seoane-Vazquez, " Assessment of FDA-Approved Drugs Not Recommended for Use or Reimbursement in Other Countries, 2017-2020 " *JAMAInternal Medicine: HEALTH CARE POLICY AND LAW* (February 13, 2023), https://jamanetwork.com/journals/jamainternalmedicine/fullarticle/2801020?guestAccessKey=0405a5f1-3465-4d9b-bf78-20791947baf0&utm_source=silverchair&utm_medium=email&utm_campaign=article_alert-jamainternalmedicine&utm_content=olf&utm_term=021323.

Philipson, Tomas and Anaupam B. Jena, "Who Benefits from New Medical Technologies? Estimates of Consumer and Producer Surpluses for HIV/AIDS Drugs," *Forum for Health Economics & Policy*, 9(3) (2006): 1-33.

Rice, Thomas, *Health Insurance Systems: An International Comparison*, Academic Press, 2021.

Salant, Steve, "Monopoly Pricing in Domestic and Foreign Markets When Manufacturer Raises the Cost of Consumer Arbitrage," (unpublished) (Oct. 22, 2022).

Samuelson, Paul A., "The Pure Theory of Public Expenditure," *Review of Economics and Statistics*, 36(4) (Nov., 1954): 387-389.

Samuelson, Paul A., "Diagrammatic Exposition of a Theory of Public Expenditure," *Review of Economics and Statistics*, 37(4) (Nov., 1955): pp. 350-356.

Sandler, Todd and Jon Cauley, "On the Economic Theory of Alliances," *Journal of Conflict Resolution*, 75(19) (June, 1975): 330-348.

Sandler, Todd and Keith Hartley, "Economics of Alliances: Lessons for Collective Action," *Journal of Economic Literature* 39(3) (Sept. 2001):551-559.

Scherer, F.M., "The Link between Gross Profitability and Pharmaceutical R&D Spending," *Health Affairs*, 20(5) (September 2001): 216-220.

Schweitzer, Stuart O. and William S. Comanor, "Prices of Pharmaceuticals In Poor Countries Are Much Lower Than In Wealthy Countries," *Health Affairs* 30(8) (August 2011): 1553–1561.

Shrestha, Ratna K. and James P. Hughes, "Contributions to International Public Goods and the Notion of Country Size," *FinanceArchive/Public Finance Analysis* 59(4) (2002/2003): 551-559.

Stiglitz, Joseph D. "Knowledge as a Global Pubic Good," in *Global Public Goods*, ed. by Inge Kaul, Isabelle Grunberg and Mark A. Stern, Oxford: (1999): 308-325.

U.S. Congressional Budget Office, Letter to Honorable Frank Pallone Jr. Chairman Committee on Energy and Commerce U.S. House of Representatives Washington, DC 20515 Re: Effects of Drug Price Negotiation Stemming From Title 1 of H.R. 3, the Lower Drug Costs Now Act of 2019, on Spending and Revenues Related to Part D of Medicare (Oct. 11, 2019).

US Council of Economic Advisors, *Reforming Biopharmaceutical Pricing at Home and Abroad* (Feb. 2018).

----------, *Funding the Global Benefits of Biopharmaceutical Innovation* (Feb. 2020).

Viscusi, W. Kip and Clayton J. Masterman, "Income Elasticities and Global Values of a Statistical Life," *Journal of Benefit Cost Analysis* 8(2) (2017): 226-250.

Viscusi, W. Kip, *Pricing Lives: Guideposts for a Safer Society*, Princeton University Press, 2018.

Figure 1, Reaction Functions and Nash Equilibrium

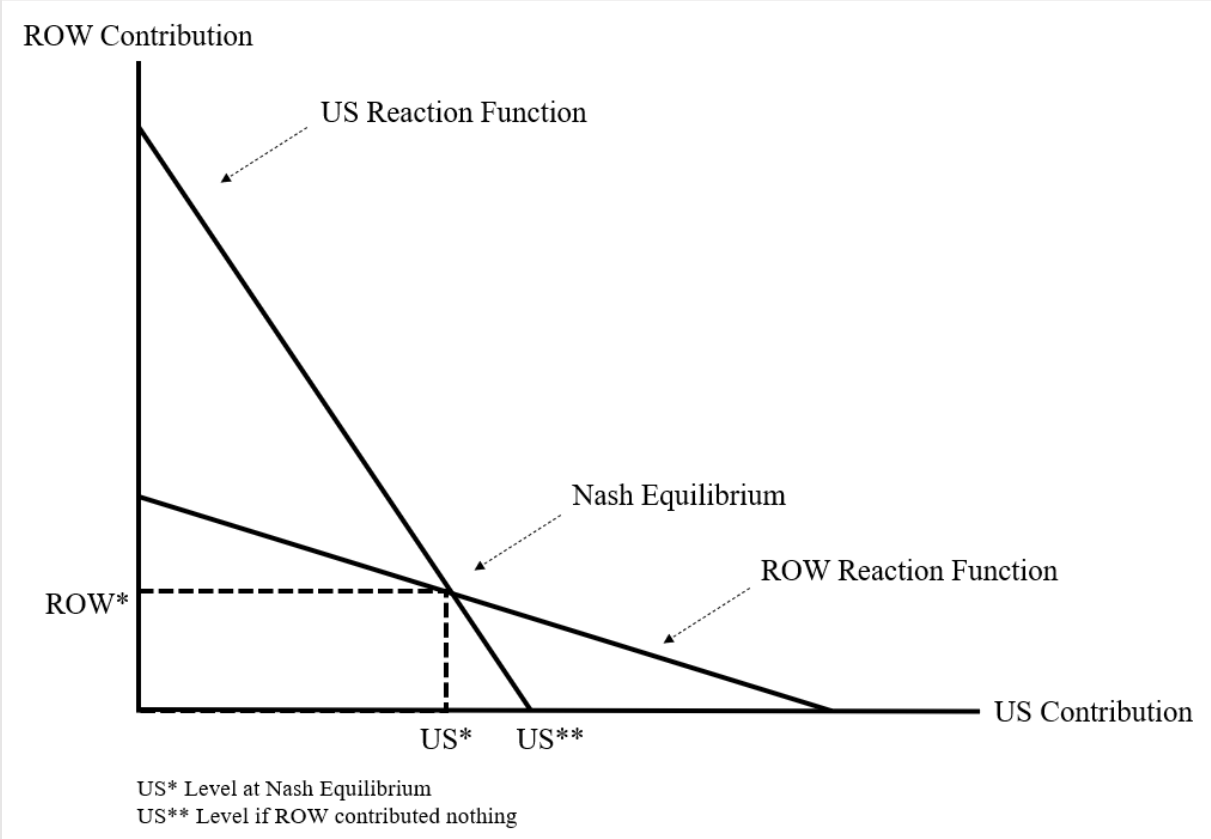

Figure 2, High Demander, Large Contribution

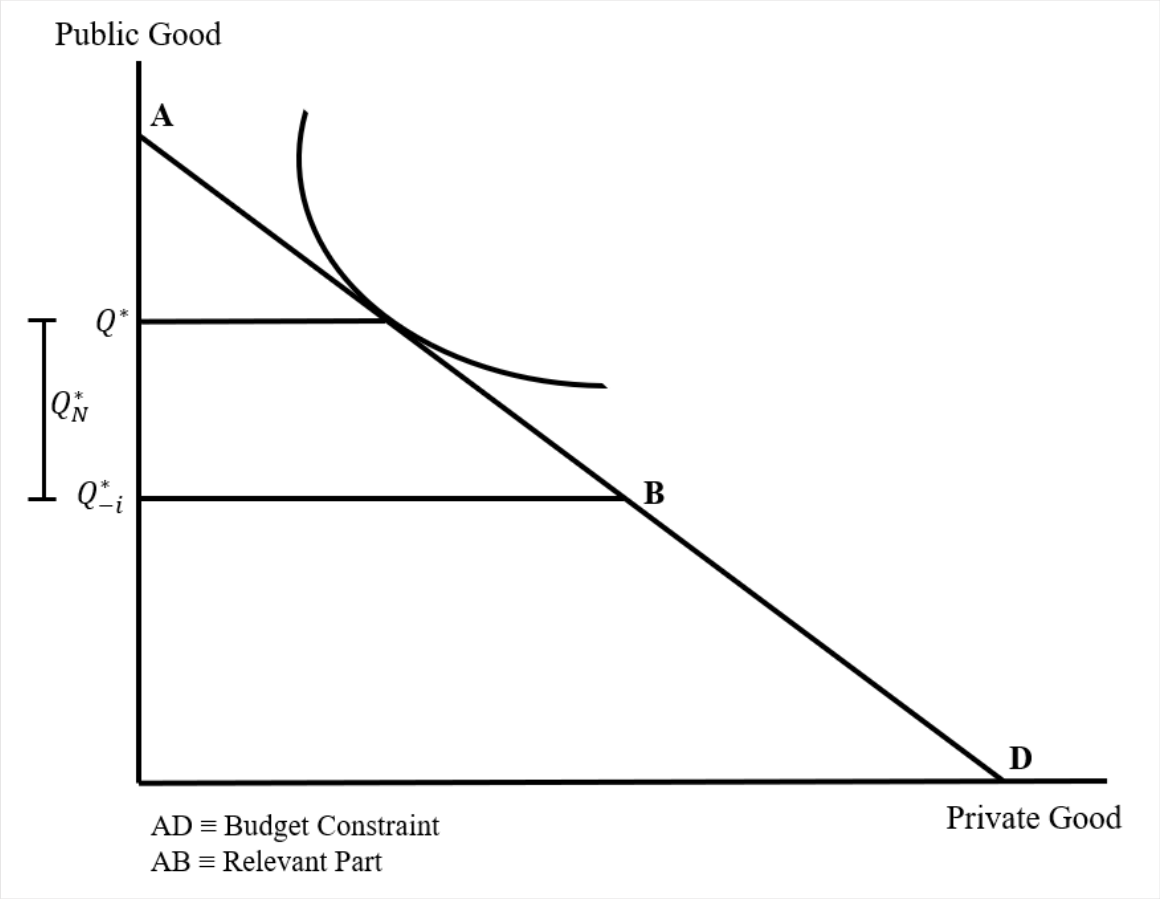

Figure 3, Medium Demander, Positive Contribution

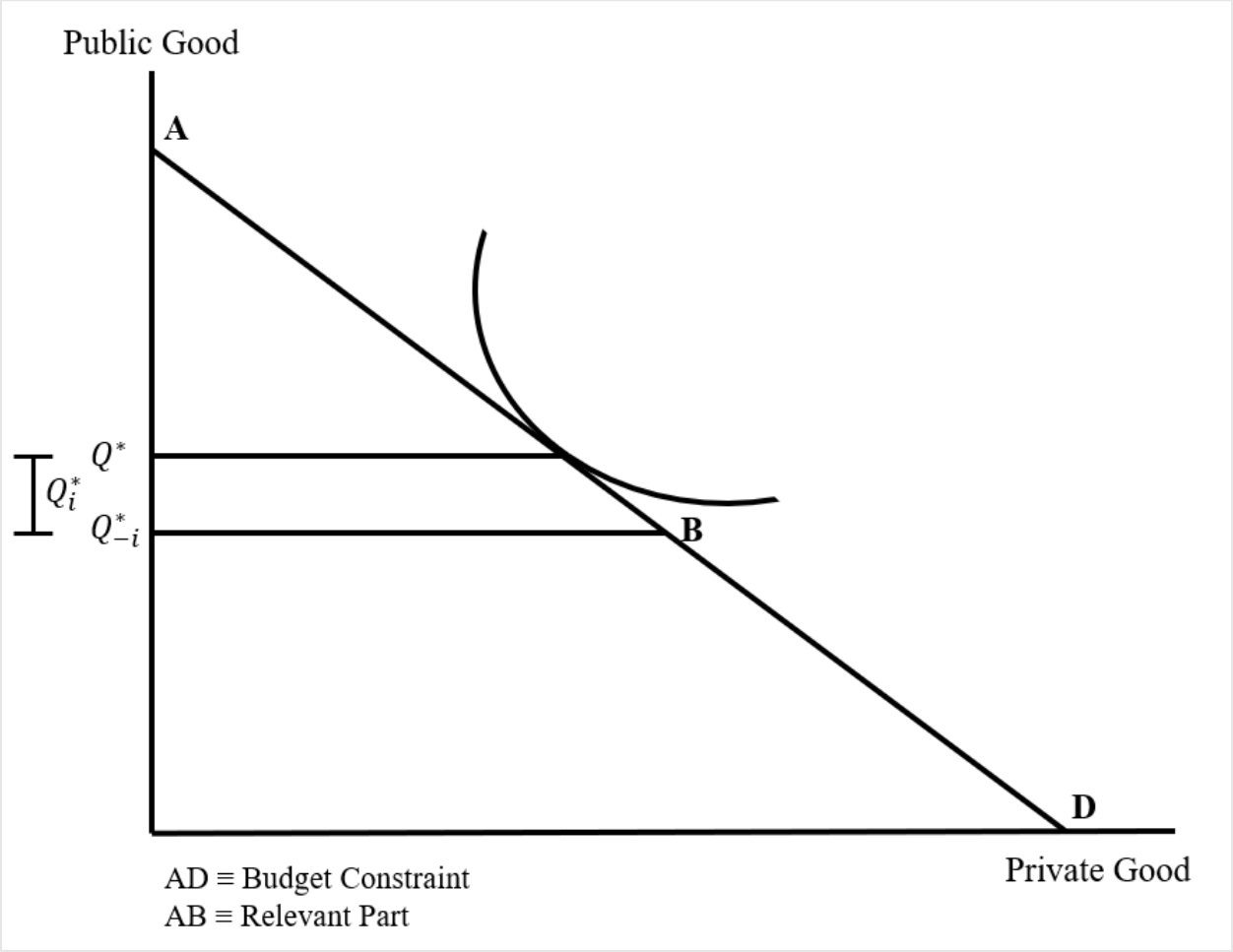

Figure 4, Low Demander, Zero Contribution

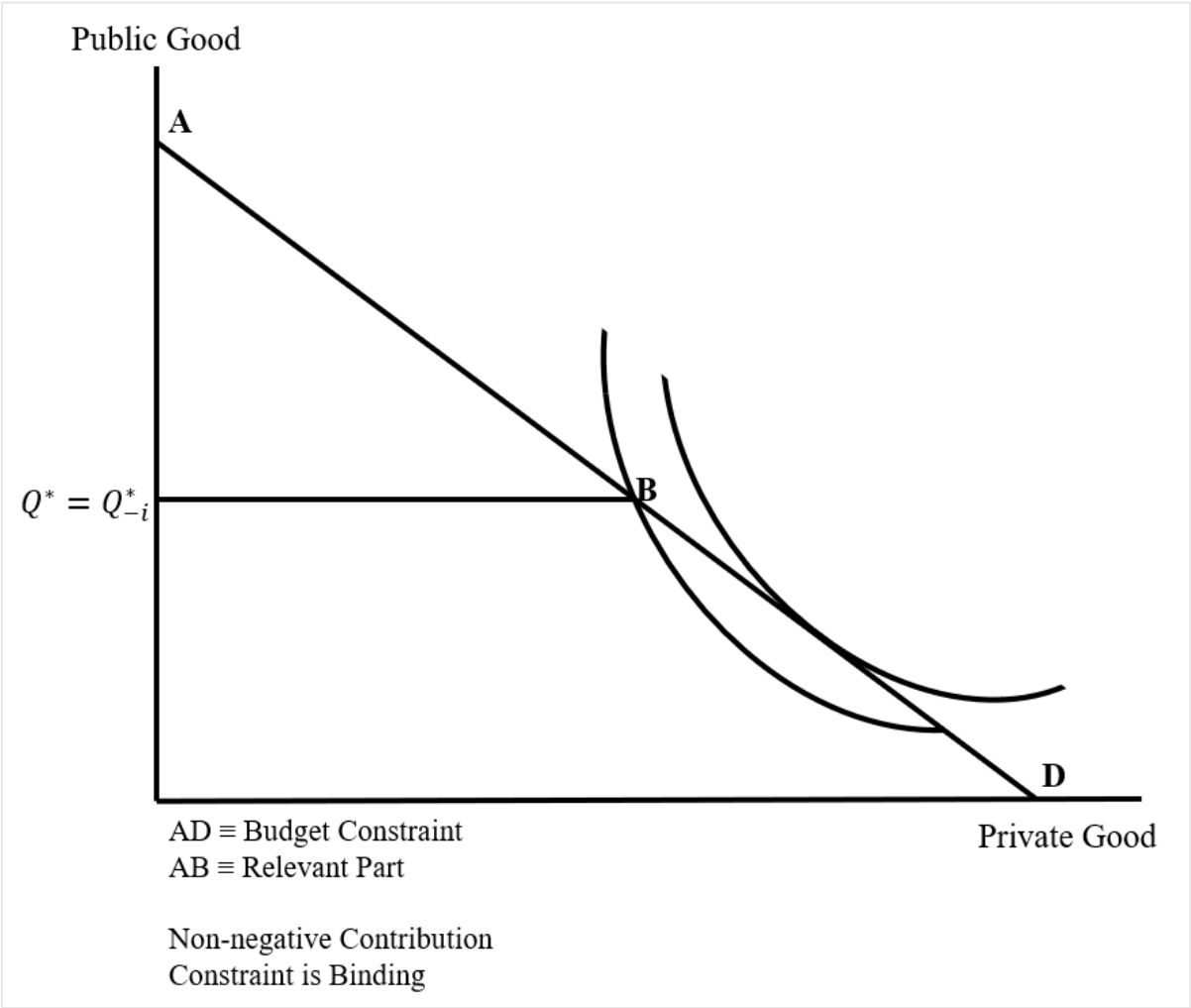

Table 1: Descriptive Statistics (n = 33)

	Mean	SD	Min	Median	Max
Contribution (MC = 24%), $ Billions	12.1	50.1	-2.4	1.0	289.2
Contribution (MC = 14.2%), $ Billions	14.9	56.6	0.0	1.7	326.4
Contribution per Capita (MC =24%), $	130.6	158.8	-31.0	106.6	884.0
Contribution per Capita (MC = 14.2%), $	192.1	176.8	0.0	171.3	998.0
GDP, $ trillions	1.8	3.6	0.0	0.6	20.4
Population (millions)	39.1	62.5	0.6	10.7	327.1
GDP per Capita, $ thousands	45.9	18.7	19.6	41.2	111.7
Brand-Name Price Index	41.8	14.2	14.2	42.4	100.0

Table 2: Correlations (n = 33)

	Contribution, MC=24% ($ Billions)	Contribution, MC=14.2% ($ Billions)	Cont per cap, MC=24% ($)	Cont per cap, MC=14.2% ($)	GDP ($ trillions)	Population (millions)	GDP per capita ($ thousands)	Brand-Name Price Index
Contribution (MC = 24%)	1	1	0.881	0.850	0.964	0.867	0.156	0.770
Contribution (MC = 14.2%)	1	1	0.883	0.853	0.970	0.876	0.152	0.771
Cont per Capita (MC = 24%)	0.881	0.883	1	0.994	0.850	0.728	0.392	0.940
Cont per Capita (MC = 14.2%)	0.850	0.853	0.994	1	0.818	0.688	0.437	0.920
GDP	0.964	0.970	0.850	0.818	1	0.958	0.098	0.753
Population	0.867	0.876	0.728	0.688	0.958	1	-0.033	0.654
GDP per Capita	0.156	0.152	0.392	0.437	0.098	-0.033	1	0.352
Brand-Name Price Index	0.770	0.771	0.940	0.920	0.753	0.654	0.352	1

Table 3: Calculated Contributions and other Data

Country	Contribution, MC=24% ($ Billions)	Contribution, MC=14.2% ($ Billions)	Cont per cap, MC=24% ($)	Cont per cap, MC=14.2% ($)	GDP ($ trillions)	Population (millions)	GDP per capita ($ thousands)	Brand-Name Price Index
Australia	2.66	4.52	106.77	181.5	1.28	24.9	51.56	38.00
Austria	1.92	2.63	216.26	295.47	0.49	8.89	55.40	50.75
Belgium	2.2	3.18	191.62	276.66	0.58	11.48	50.13	46.08
Canada	7.76	10.59	209.24	285.69	1.82	37.07	48.97	50.82
Chile	0.12	0.25	6.19	13.43	0.44	18.73	23.68	32.39
Czechia	0.86	1.31	80.25	122.51	0.42	10.67	39.82	42.60
Estonia	-0.01	0.05	-10.64	36.91	0.05	1.32	35.56	21.81
Finland	0.97	1.37	174.82	247.6	0.26	5.52	46.77	47.54
France	9.62	14.64	143.25	217.89	2.97	67.19	44.14	42.80
Germany	16.46	21.96	198.06	264.17	4.28	83.12	51.43	53.35
Greece	-0.33	0.67	-30.99	63.8	0.3	10.52	28.30	20.80
Hungary	0.74	1.13	75.72	116.47	0.31	9.71	31.78	42.20
Ireland	0.97	1.33	201.26	276.93	0.44	4.82	90.30	50.06
Italy	11.82	16.77	194.91	276.58	2.5	60.63	41.22	47.38
Japan	28.87	40.4	226.99	317.57	4.98	127.2	39.18	48.55
Latvia	0.04	0.11	23.3	56.97	0.06	1.93	30.29	30.78
Lithuania	0.04	0.17	14.21	60.14	0.1	2.8	35.04	27.03
Luxembourg	0.05	0.1	83.94	171.28	0.07	0.6	111.70	33.42
Mexico	1.01	1.61	8.03	12.76	2.47	126.19	19.58	40.63
Netherlands	1.03	1.68	60.26	98.19	0.94	17.06	55.09	39.57
New Zealand	0.34	0.51	72.5	108.31	0.2	4.74	41.28	43.83
Norway	0.86	1.31	160.53	246.04	0.34	5.34	64.11	42.39
Poland	1.51	2.34	39.82	61.61	1.19	37.92	31.50	41.91
Portugal	1.09	1.76	106.62	172	0.34	10.26	33.30	39.98
Rep. of Korea	0.99	3.42	19.41	66.82	2.1	51.17	41.08	28.01
Slovakia	0.3	0.56	54.23	103.36	0.17	5.45	31.67	34.81
Slovenia	0.19	0.33	92.8	160.81	0.08	2.08	38.51	37.37
Spain	9.49	13.03	203.17	279.13	1.9	46.69	40.67	50.21
Sweden	1.56	2.29	156.67	230.02	0.55	9.97	55.39	44.93
Switzerland	2.25	3.02	263.89	354.11	0.61	8.53	71.62	52.66
Turkey	-2.37	0	-28.76	0	2.21	82.34	26.86	14.20
United Kingdom	7.37	11.23	109.83	167.31	3.08	67.14	45.88	42.72
United States	289.16	326.44	884.04	998.01	20.37	327.1	62.27	100.00
Total	399.55	490.72						
World without US	110.39	164.28						

Table 4: Explaining Contribution by Country

MC = 14.2% of US Price Index

Dependent Variable:	Log of Total Contribution (MC = 14.2%)				
Model:	(1)	(2)	(3)	(4)	(5)
Variables					
Constant	1.28***	1.22***	1.19***	1.17***	1.15***
	(0.132)	(0.141)	(0.151)	(0.170)	(0.177)
Log of GDP ($ trillions)	1.23***	1.17***	1.14***	1.13***	1.13***
	(0.078)	(0.085)	(0.093)	(0.107)	(0.109)
1(US)		1.03**	1.16**	1.21*	1.24*
		(0.361)	(0.397)	(0.459)	(0.471)
1(Japan)			0.678*	0.715*	0.739*
			(0.274)	(0.317)	(0.326)
1(Germany)				0.279	0.303
				(0.301)	(0.310)
1(Switzerland)					0.513**
					(0.144)
Fit statistics					
Observations	32	32	32	32	32
R^2	0.885	0.893	0.896	0.897	0.899
Adjusted R^2	0.881	0.885	0.885	0.882	0.880
Dependent variable mean	0.70	0.70	0.70	0.70	0.70

Heteroskedasticity-robust standard-errors in parentheses
*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

Table 5: Explaining Contribution by Country

Market Size (GDP) and Contribution

MC = 24% of US Price Index

Dependent Variable:	Log of Total Contribution (MC = 24%)				
Model:	(1)	(2)	(3)	(4)	(5)
Variables					
Constant	0.832***	0.764***	0.722***	0.695**	0.667**
	(0.163)	(0.173)	(0.187)	(0.209)	(0.217)
Log of GDP ($ trillions)	1.29***	1.21***	1.18***	1.16***	1.16***
	(0.104)	(0.115)	(0.128)	(0.146)	(0.148)
1(US)		1.24*	1.39*	1.48*	1.51*
		(0.458)	(0.512)	(0.592)	(0.605)
1(Japan)			0.746*	0.806	0.838
			(0.345)	(0.399)	(0.409)
1(Germany)				0.422	0.453
				(0.379)	(0.389)
1(Switzerland)					0.714***
					(0.181)
Fit statistics					
Observations	30	30	30	30	30
R^2	0.834	0.844	0.848	0.850	0.854
Adjusted R^2	0.828	0.833	0.831	0.826	0.824
Dependent variable mean	0.37	0.37	0.37	0.37	0.37

Heteroskedasticity-robust standard-errors in parentheses

*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*