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[CORRECTED VERSION]

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Pharmaceutical Price Discrimination and Social Welfare

Frank R. Lichtenberg

[Corrected Version]

Abstract

Price discrimination is an extremely common type of pricing strategy engaged in by virtually every business with some discretionary pricing power. The issue of whether price discrimination reduces or increases social welfare has been considered by economists since at least 1920. At that time, it was demonstrated that, under certain (restrictive) conditions, price discrimination will reduce social welfare. Subsequent research has shown that price discrimination can increase social welfare, and that a necessary (but not a sufficient) condition for welfare to rise is that total output with discrimination exceeds the no-discrimination level.

First, we present evidence about international drug price differentials. Drug prices in the top 5 countries are almost five times as high as they are in the bottom five countries. Certain features of the drug price distribution are surprising. For example, according to our drug price index, the price of drugs in Mexico (which has the second-highest drug prices) is 24% higher than it is in the U.S. (which ranks sixth out of 38 countries). There is a highly significant positive correlation between per capita income and the drug price index: on average, the price of drugs is lower in low-income countries. However, there are large deviations from the regression line. Countries (particularly low-income countries) with similar levels of income pay vastly different prices for drugs.

Next, we examine income-related price differentials in the U.S. When price is defined as the amount paid by the patient, there is an inverted-U-shaped relationship between income and price. People in the lowest income category pay 25% less than high income people (16% less if cases when the patient paid nothing are excluded), but people in the middle income category (whose income is 125-200% of the poverty line) pay 6% more than high income people (whose income exceeds 400% of the poverty line).

We perform an empirical investigation of whether the necessary condition for price discrimination to increase welfare—that it increase total output—is satisfied in the case of international pharmaceutical prices, by analyzing the relationship across drugs between total output growth and growth in international price dispersion. Drugs that had larger increases in international price dispersion had larger increases in total utilization, controlling for the growth in the mean price of the drug and the drug's vintage. Numerous studies have shown that increased prescription drug use results in improved health outcomes, or the converse: reductions in drug use result in worse health outcomes, such as higher risk of hospitalization and death.

In addition to increasing the output of existing products, the ability to engage in price discrimination is likely to increase the number of new products. Contrary to the assumptions of some theoretical models, some markets that would not be served under uniform pricing will be served under price discrimination. This would be the case whenever there are fixed production costs, and the pharmaceutical industry has much higher fixed costs (especially R&D expense) as a percentage of sales than most other industries. Studies have shown that the amount of pharmaceutical R&D investment is influenced by factors (other than the ability to price discriminate) that determine the expected profitability of investment. Studies have also provided evidence that the development and use of new drugs has resulted in significant increases in longevity and health, and that overall, new drugs have been highly cost-effective.

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Introduction

Price discrimination occurs when a firm charges different prices to different groups of consumers for an identical good or service, for reasons not associated with costs. Price discrimination is potentially profitable if the price elasticity of demand varies across groups. In that case, the firm has the incentive to charge a higher price to the group with a more price inelastic demand, and a lower price to the group with a more elastic demand. For the firm to engage in price discrimination, there must be barriers to prevent consumers from switching from one supplier to another: the firm must be able to prevent *arbitrage* – defined as a process whereby consumers who have purchased a good or service at a lower price are able to re-sell it to those consumers who would have normally paid the higher price.

Price discrimination is an extremely common type of pricing strategy operated by virtually every business with some discretionary pricing power. Third-degree (multi-market) price discrimination--charging different prices for the same product in different segments of the market**--**is the most common form of price discrimination. When firms engage in third-degree price discrimination, consumers with greater willingness or ability to pay for a good or service pay a higher price for it, and prices charged may bear little or no relation to the cost of production. The market is usually separated in two ways: by time or by geography. For example, exporters may charge a lower price in overseas markets if demand is estimated to be more elastic than it is in home markets.

Suppose there are two groups of consumers: low-income (foreign) consumers and high-income (domestic) consumers. Also, suppose that demand by low-income consumers is more elastic. Therefore, if price discrimination is feasible, the price charged to low-income consumers (P_L) will be lower than the price charged to high-income consumers (P_H): $P_L < P_H$.

Suppose that, if the firm could not engage in price discrimination—due to inability to prevent arbitrage—its profit-maximizing price would be P. This price would always be in-between P_L and P_H: $P_L < P < P_H$. It is clear that (1) the firm, and (2) low-income consumers, are better off under price discrimination than they are under uniform pricing. Uniform pricing imposes the constraint that $P_L = P_H$, and unconstrained maximum profits are generally higher than constrained maximum profits. Low-income consumers are better off because they face a lower price, and obtain higher consumer surplus, under price discrimination. It appears that high-income consumers are worse off under price discrimination (because $P < P_H$), but we will argue that this is not necessarily the case.

Two questions have been discussed in both economics textbooks and the academic literature: (1) are consumers as a whole better off under price discrimination?; and (2) is society as a whole better off under price

discrimination? The wellbeing of consumers as a whole might be measured by ($CS_L + \theta_H CS_H$), where CS_L = consumer surplus of low-income consumers, CS_H = consumer surplus of high-income consumers, and θ_H = the "weight" given to high-income consumers relative to the weight given to low-income consumers. If increasing the wellbeing of low-income consumers was considered more important than increasing the well-being of high-income consumers, $\theta_H < 1$.

If price discrimination increases CS_L and reduces CS_H, its net effect on consumer wellbeing is ambiguous. Let $CS_{L,D}$ = consumer surplus of low-income consumers under price discrimination, $CS_{L,U}$ = consumer surplus of low-income consumers under uniform pricing, etc. Then price discrimination will increase overall consumer wellbeing if $(CS_{L,D} - CS_{L,U}) > \theta_H (CS_{H,U} - CS_{H,D})$. Clearly, the lower θ_H is, the more likely this is to be true. Although Riley (2006) asserts that "consumer surplus is reduced in most cases" by price discrimination, he offers no empirical support for that statement and the direction of the effect is theoretically ambiguous.

Since profits are generally higher under price discrimination than under uniform pricing, the ability to price discriminate is more likely to increase the wellbeing of society as a whole ("social welfare") than it is to increase consumer wellbeing. Let us define social welfare as ($CS_L + \theta_H CS_H + \theta_\pi \pi$), where π = producer profits, and θ_π = the "weight" given to producer profits relative to the weight given to low-income consumers. If increasing the wellbeing of low-income consumers was considered more important than increasing producer profits, $\theta_\pi < 1$. Then price discrimination will increase overall consumer wellbeing if $(CS_{L,D} - CS_{L,U}) + \theta_\pi (\pi_D - \pi_U) > \theta_H (CS_{H,U} - CS_{H,D})$.

The issue of whether price discrimination reduces or increases social welfare has been considered by economists since at least 1920. In that year, Pigou demonstrated that under certain assumptions, price discrimination will reduce social welfare. In particular, he showed that price discrimination will reduce social welfare if all of the following conditions hold: (1) all markets are served at the non-discriminatory price; (2) surpluses obtained by all groups of consumers and profits have equal weight in social welfare; and (3) all demand functions are linear. Under these conditions, total output under price discrimination is the same as it is under uniform pricing, but output is allocated less efficiently under price discrimination. Varian (1985), following Schmalensee (1981), showed generally that a necessary (but not a sufficient) condition for welfare to rise is that total output with discrimination exceeds the no-discrimination level (see also Schwartz, 1990).

Subsequent research has shown that if not all of the above conditions are satisfied, price discrimination can increase output and raise social welfare. Some authors have relaxed the third assumption (linear demand curves). When (some) demand curves are nonlinear, price discrimination can increase total output.

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Cowan (2008) shows that welfare rises if inverse demand in the low-price market is more convex (at the discriminatory price) than inverse demand in the high-price market and the discriminatory prices are close together, so the cost of misallocation is less than the benefit of higher output. Moreover, he finds that "the conditions for discrimination to raise welfare are plausible."

This paper has three main objectives. First, we will present two kinds of evidence about the relationship between income and drug prices: international evidence, and evidence from the USA. Second, we will perform an empirical investigation of whether the necessary condition for price discrimination to increase welfare—that it increases total output—is satisfied in the case of international pharmaceutical prices. Third, we will consider arguments and empirical evidence that suggest that the first assumption above—that all markets served under price discrimination are also served under uniform pricing—may be violated in the case of pharmaceutical markets.[1]

International pharmaceutical price differentials

We will use comprehensive quarterly time-series data provided by IMS Health on the quantity and value of almost 6500 drugs sold in 38 countries during the period 1999Q1-2008Q3.[2] The price of the drug will be defined as its "unit value": manufacturer revenue per standard dose unit. Let

Q_{cdt} = the quantity (number of standard 'dose' units[3]) of drug d sold in country c in period t (d = 1, 2, …, 6499; c = 1, 2, …, 38; t = 1999Q1-2008Q3)

V_{cdt} = the value[4] of drug d sold in country c in period t

P_{cdt} = V_{cdt} / Q_{cdt} = the "price" (manufacturer revenue per standard unit) of drug d sold in country c in period t

Drugs are defined in terms of the active ingredients (molecules) they contain. Q_{dct} is the quantity (and V_{dct} is the value) of standard units sold in country c in year t that contain active ingredient d. If a drug is a combination drug (containing multiple active ingredients), it will be counted more than once.

[1] Consequently, price discrimination may increase total output, from zero to a positive amount.
[2] The dataset contains over 2.7 million observations.
[3] For oral solid forms, the standard unit factor is one tablet or capsule; for syrup forms, the standard unit factor is one teaspoon (5ml); and for injectable forms, it is one ampoule or vial. Standard units are used because drug packs or products may be in different forms.
[4] Manufacturer sales revenue in US dollars at the exchange rates in effect at the time the sales were made.

Our measure of price—manufacturer revenue per standard dose unit—is clearly imperfect. One important reason for this is that manufacturers frequently offer rebates to drug purchasers, but we have no information about the magnitude of these rebates. Hence, we do not observe the revenue received by the manufacturer net of rebates. Also, in some countries a substantial share of drug expenditure is paid for by public or private insurance, so the revenue received by the manufacturer (net of rebates) exceeds the amount paid by consumers.

Table 1 shows the countries in our sample, ranked by the total number of standard units sold during the period 1999Q1-2008Q3. Table 2 shows the top 50 drugs in our sample, ranked by the total number of standard units sold during the period 1999Q1-2008Q3.

An index of the relative prices of drugs in different countries in 2008Q3 can be constructed by estimating the following model via weighted least-squares, weighting by $Q_{cd,2008Q3}$:

$$\ln P_{cd,2008Q3} = \alpha_d + \delta_c + \varepsilon_{cd,2008Q3} \qquad (1)$$

where

$P_{cd,2008Q3}$ = the price (unit value) of drug d sold in country c in 2008Q3
$Q_{cd,2008Q3}$ = the quantity (number of standard units) of drug d sold in country c in 2008Q3
α_d = a fixed effect for drug d
δ_c = a fixed effect for country c
$\varepsilon_{cd,2008Q3}$ = a disturbance

Since eq. (1) includes drug fixed effects, the country fixed effects measure (utilization-weighted) average differences across countries in drug prices, controlling for international differences in the mix of drugs sold. $\exp(\delta_c - \delta_{USA})$ may be interpreted as the mean price of drugs in country c, relative to the price of drugs in the U.S.

Values of this price index are displayed in Figure 1. Drug prices vary considerably across countries. Drug prices in the top 5 countries are almost five times as high as they are in the bottom five countries. Certain features of the drug price distribution are surprising. For example, according to this index, the price of drugs in Mexico (which has the second-highest drug prices) is 24% higher than it is in the U.S. (which ranks sixth out of 38 countries).

The relationship across countries between per capita income (in U.S. dollars in 2006) and the 2008Q3 drug price index is depicted in Figure 2. There is a highly significant (p-value=.0001) positive correlation between per capita income and the drug price index. On average, the price of drugs is lower in low-

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Table 1

Countries in our sample, ranked by number of standard units sold during the period 1999Q1-2008Q3

country	Millions of standard units
USA	511,271
INDIA	367,832
JAPAN	324,804
GERMANY	160,759
KOREA	155,975
FRANCE	148,940
INDONESIA	130,282
UK	100,362
BRAZIL	99,077
ITALY	70,073
CHINA	67,173
CANADA	64,767
MEXICO	62,459
POLAND	61,312
SPAIN	58,484
EGYPT	46,727
TURKEY	42,001
TAIWAN	40,718
AUSTRALIA	40,495
THAILAND	28,543
PHILIPPINES	27,641
SOUTH AFRICA	16,782
SWITZERLAND	15,878
BELGIUM	14,692
AUSTRIA	14,284
PORTUGAL	14,052
GREECE	13,852
SWEDEN	13,568
SAUDI ARABIA	13,077
NETHERLANDS	12,463
ALGERIA	11,630
MOROCCO	9,431
FINLAND	8,173
FR_W_AFRICA	8,151
MALAYSIA	7,175
TUNISIA	6,078
SINGAPORE	3,071
PUERTO RICO	2,445

Table 2

Top 50 drugs in our sample, ranked by number of standard units sold during the period 1999Q1-2008Q3

Rank	active_ingredient	Millions of standard units		Rank	active_ingredient	Millions of standard units
1	PARACETAMOL	77,550		26	PANTOTHENIC ACID	16,554
2	PYRIDOXINE	43,996		27	CHLORHEXIDINE	16,210
3	SODIUM	39,688		28	ALUMINIUM	16,027
4	SALBUTAMOL	38,947		29	DEXAMETHASONE	15,330
5	THIAMINE	35,472		30	DICLOFENAC	15,303
6	MAGNESIUM	34,534		31	METFORMIN	14,494
7	ASCORBIC ACID	33,467		32	IRON FERROUS	13,844
8	CALCIUM	32,889		33	POVIDONE-IODINE	13,653
9	NICOTINAMIDE	32,101		34	HYDROCHLOROTHIAZIDE	13,618
10	ACETYLSALICYLIC ACID	32,041		35	TAURINE	13,026
11	CYANOCOBALAMIN	31,492		36	CAMPHOR	12,853
12	RIBOFLAVIN	30,852		37	NEOMYCIN	12,777
13	CAFFEINE	29,221		38	COLECALCIFEROL	12,462
14	ZINC	28,460		39	TETRYZOLINE	12,248
15	CHLORPHENAMINE	27,652		40	BETAMETHASONE	12,215
16	MENTHOL	26,859		41	BORIC ACID	12,158
17	VITAMIN E	23,664		42	HYDROGEN PEROXIDE	12,035
18	POTASSIUM	23,176		43	LEVOTHYROXINE SODIUM	11,608
19	NAPHAZOLINE	20,759		44	CODEINE	11,097
20	IBUPROFEN	20,665		45	AMOXICILLIN	11,015
21	RETINOL	18,956		46	PSEUDOEPHEDRINE	10,785
22	SALICYLIC ACID	18,555		47	2-PROPANOL	10,494
23	PARAFFIN OIL	17,569		48	CHLORAMPHENICOL	10,464
24	BENZALKONIUM CHLORIDE	16,889		49	PIRENOXINE	10,264
25	FOLIC ACID	16,600		50	DEXTROMETHORPHAN	10,253

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Figure 1
Mean price relative to US price: exp(δ_c - δ_{USA})

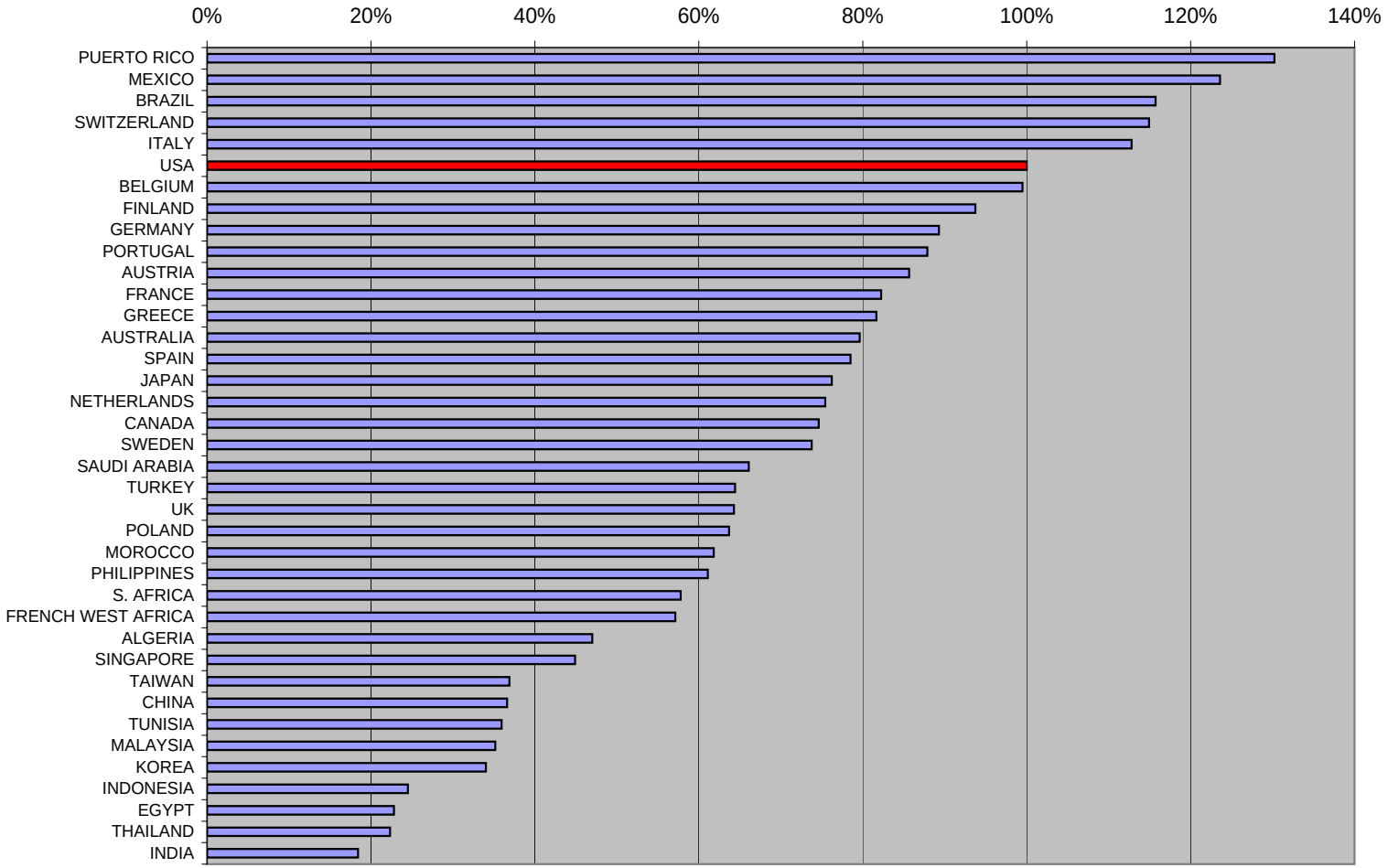
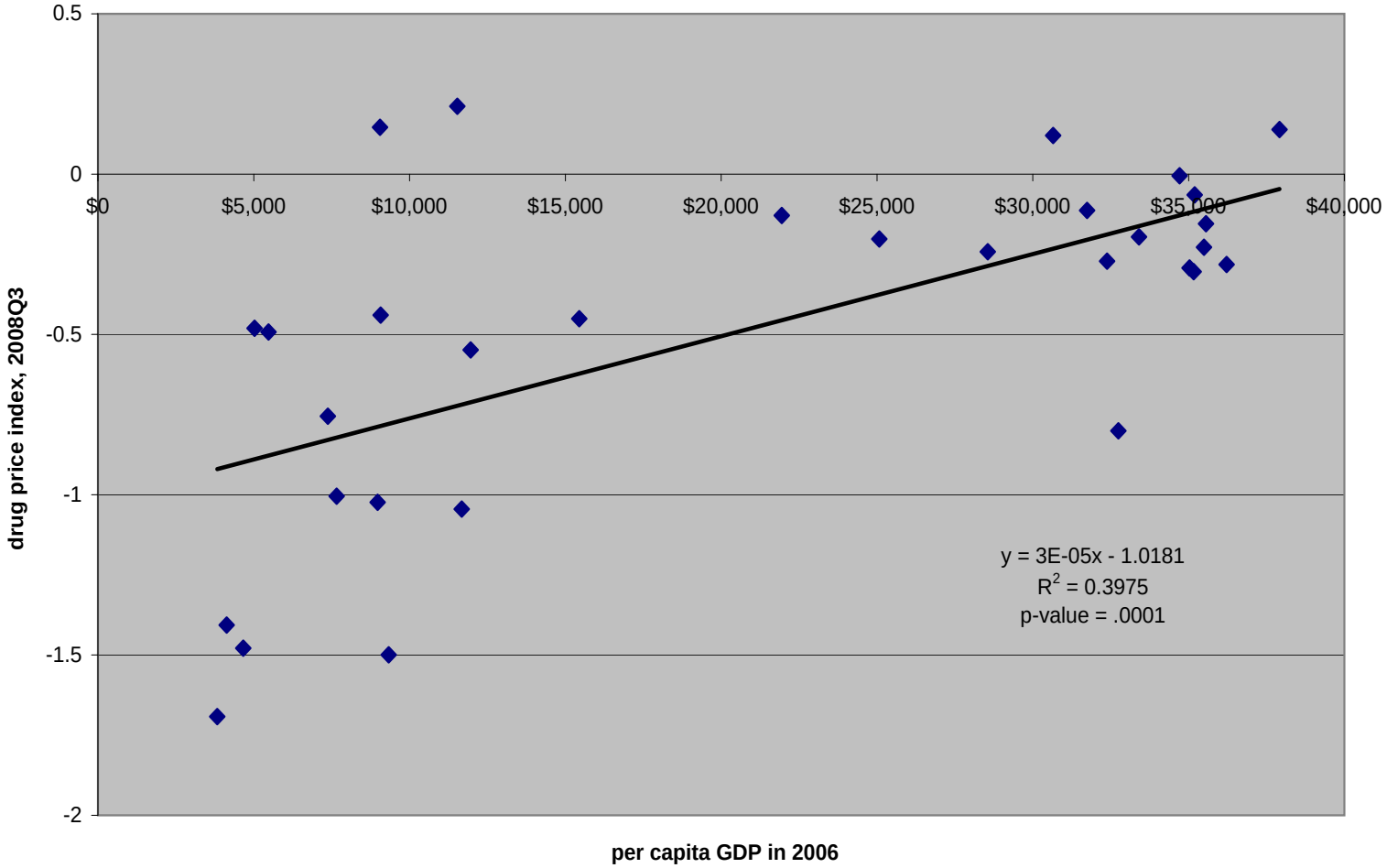


Figure 2
Relationship across countries between per capita income and drug price index



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income countries. However, there are large deviations from the regression line. Countries (particularly low-income countries) with similar levels of income pay vastly different prices for drugs.

Pharmaceutical price differentials within the U.S.

Now we will provide some evidence about income-related drug price differentials *within the U.S.* using data from the 1996-2006 Medical Expenditure Panel Survey (MEPS). MEPS is a set of large-scale surveys of families and individuals, their medical providers (doctors, hospitals, pharmacies, etc.), and employers across the United States. MEPS collects data on the specific health services that Americans use, how frequently they use them, the cost of these services, and how they are paid for, as well as data on the cost, scope, and breadth of health insurance held by and available to U.S. workers. For a representative sample of households, MEPS provides data on the household's income, a list of all prescriptions used by each member of the household, and the amounts paid (by the patient and others) for each prescription. We can define the "amount paid" in three different ways: (1) the total amount paid by all payors (patient + third parties);[5] (2) the amount paid by the patient, excluding cases when the patient paid nothing (e.g. because the product was a free sample); and (3) the amount paid by the patient, including cases when the patient paid nothing. Data on about 2.4 million prescriptions are available from the 1996-2006 waves of MEPS.

Income-related differences in the amount paid for the same drugs can be calculated by estimating the following model:

$$\log P_{ipt} = \beta_1 \, INCOME1_{ipt} + \beta_2 \, INCOME2_{ipt} + \beta_3 \, INCOME3_{ipt} + \beta_4 \, INCOME4_{ipt} + \beta_5 \, INCOME5_{ipt} + \alpha_{pt} + \varepsilon_{ipt} \qquad (2)$$

where

P_{ipt} = the amount paid for the i^{th} prescription for product (NDC code) p in year t

$INCOME1_{ipt}$ = 1 if the i^{th} prescription for product p in year t was consumed by a person in income category 1 (income below poverty line)

… …

$INCOME5_{ipt}$ = 1 if the i^{th} prescription for product p in year t was consumed by a person in income category 5 (high income)

α_{pt} = a fixed effect for product p in year t

[5] The amount paid does not account for manufacturer rebates.

For example, (β_1 - β_5) is an estimate of the difference between the amounts paid by members of the lowest income category and from the highest income category for the same drug.

Estimates of income-related price differentials (% deviations from prices paid by high-income people) in the U.S. are shown in Figure 3. When price is defined as total amount paid by all payers, price is positively correlated with income, but the price differences are quite small: the price paid for prescriptions consumed by the poorest households is less than 3% lower than the price paid for prescriptions consumed by the richest households. When price is defined as the amount paid by the patient (either including or excluding cases when the patient paid nothing), there is an inverted-U-shaped relationship between income and price. People in the lowest income category pay 25% less than high income people (16% less if cases when the patient paid nothing are excluded), but people in the middle income category (whose income is 125-200% of the poverty line) pay 6% more than high income people (whose income exceeds 400% of the poverty line). This is presumably due to the fact that people in the middle of the income distribution are less likely to have prescription drug insurance than either high-income people (who have employer-based coverage) or people below the poverty line (who have Medicaid coverage).

The relationship between total output growth and growth in international price dispersion

As discussed above, previous investigators have shown that for price discrimination to increase social welfare, it must increase total output. In this section, we perform an empirical investigation of whether this necessary condition for price discrimination to increase welfare is satisfied in the case of international pharmaceutical prices.

We will analyze the relationship across drugs between total output growth and growth in international price dispersion (and other variables) by computing weighted least-squares estimates of models of the form:

$$Q'_d = \beta\, CV\_P'_d + \gamma\, X_d + \varepsilon_d \qquad (3)$$

where

Q'_d = the growth rate of the total quantity of drug d sold in all countries
$CV\_P'_d$ = the growth rate of the (weighted) coefficient of (international) variation of the price of drug d
X_d = a vector of other characteristics of drug d

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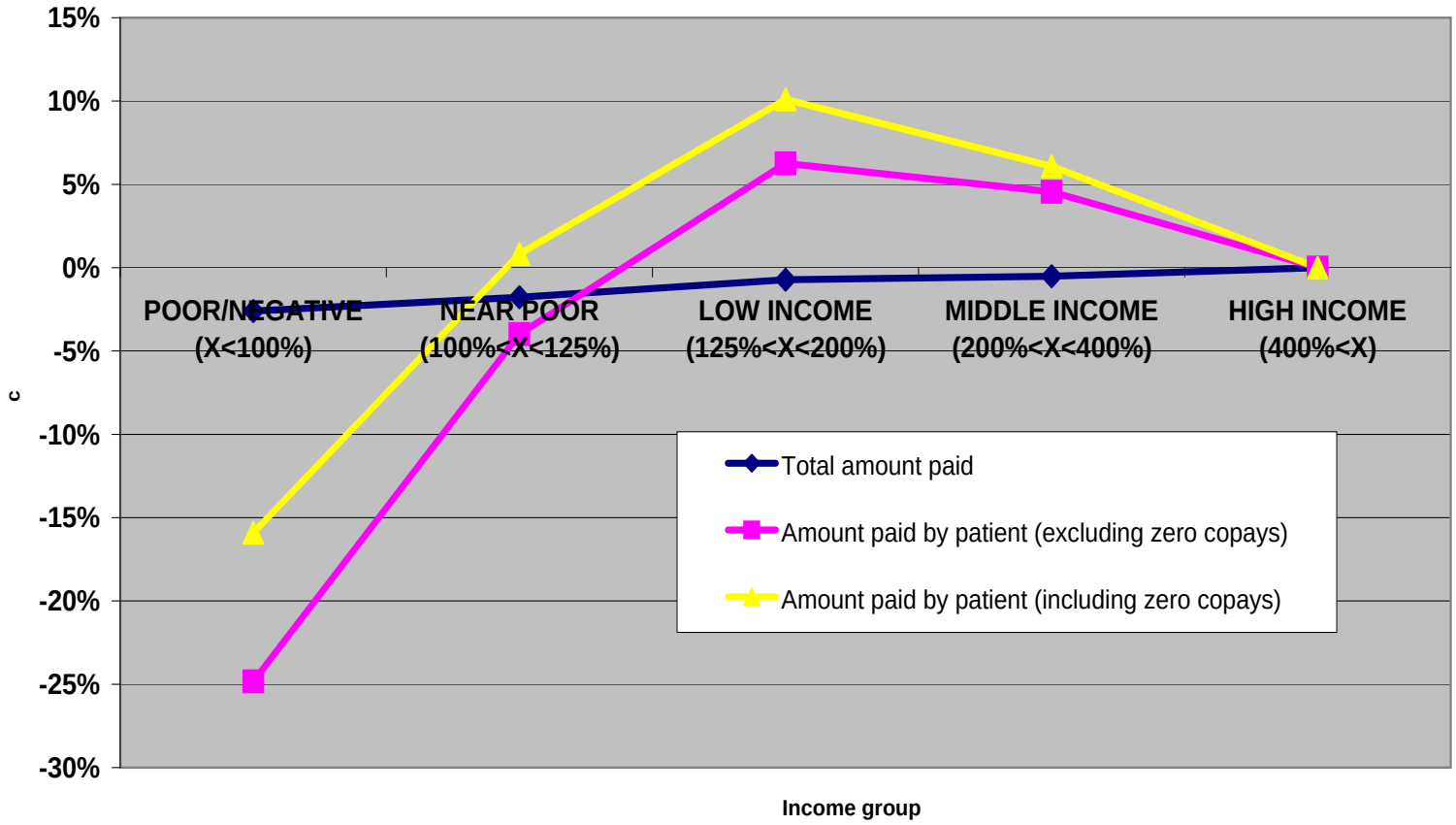
Figure 3
Income-related price differentials in the U.S.:
% deviations from price paid by high-income people



Source: Author's calculations based on 2.4 million 1996-2006 Medical Expenditure Panel Survey prescriptions

The weight we will use is the total quantity of drug d sold in all countries during the entire period, i.e. $Q_{.d.} = \Sigma_c \Sigma_t Q_{cdt}$. Weighted least squares is appropriate because, as shown in Figure 4, Q' exhibits heteroskedasticity: the variance of the growth rate of the total quantity of drug d sold in all countries is lower for highly-utilized drugs.

The growth rate of the total quantity of drug d sold in all countries (Q'_d) is calculated as the slope (γ_d) of the regression of $\ln(Q_{.dt})$ on a time trend:

$$\ln Q_{.dt} = \theta_d + \gamma_d t + \varepsilon_{.dt} \quad (4)$$

where

$Q_{.dt} = \Sigma_c Q_{cdt}$ = the total quantity of drug d sold in all countries in period t

Similarly, the growth rate of the (weighted) coefficient of (international) variation of the price of drug d ($CV\_P'_d$) is calculated as the slope (π_d) of the regression of $\ln(CV\_P_{.dt})$ on a time trend:

$$\ln CV\_P_{.dt} = \rho_d + \pi_d t + \varepsilon_{.dt} \quad (5)$$

where

$CV\_P_{.dt}$ = $SD\_P_{.dt}$ / $MEAN\_P_{.dt}$ = the (weighted) coefficient of (international) variation of the price of drug d in period t

$SD\_P_{.dt}$ = $[\Sigma_c Q_{cdt} (P_{cdt} - MEAN\_P_{.dt})^2] / \Sigma_c Q_{cdt}$ = the (weighted) standard deviation of the price of drug d in period t

$MEAN\_P_{.dt}$ = $\Sigma_c Q_{cdt} P_{cdt} / \Sigma_c Q_{cdt}$ = the (weighted) mean price of drug d in period t

In some models we will control for one or two covariates. The first is the growth rate of the mean price of drug d ($MEAN\_P'_d$), calculated as the slope (φ_d) of the regression of $\ln(MEAN\_P_{.dt})$ on a time trend:

$$\ln MEAN\_P_{.dt} = \sigma_d + \varphi_d t + \varepsilon_{.dt} \quad (6)$$

Under certain assumptions, the coefficient on $MEAN\_P'_d$ in eq. (3) could be interpreted as a price elasticity of demand.

The second covariate is the vintage of drug d (INN_YEAR_d), defined as the year in which the drug's International Nonproprietary Name (INN) was

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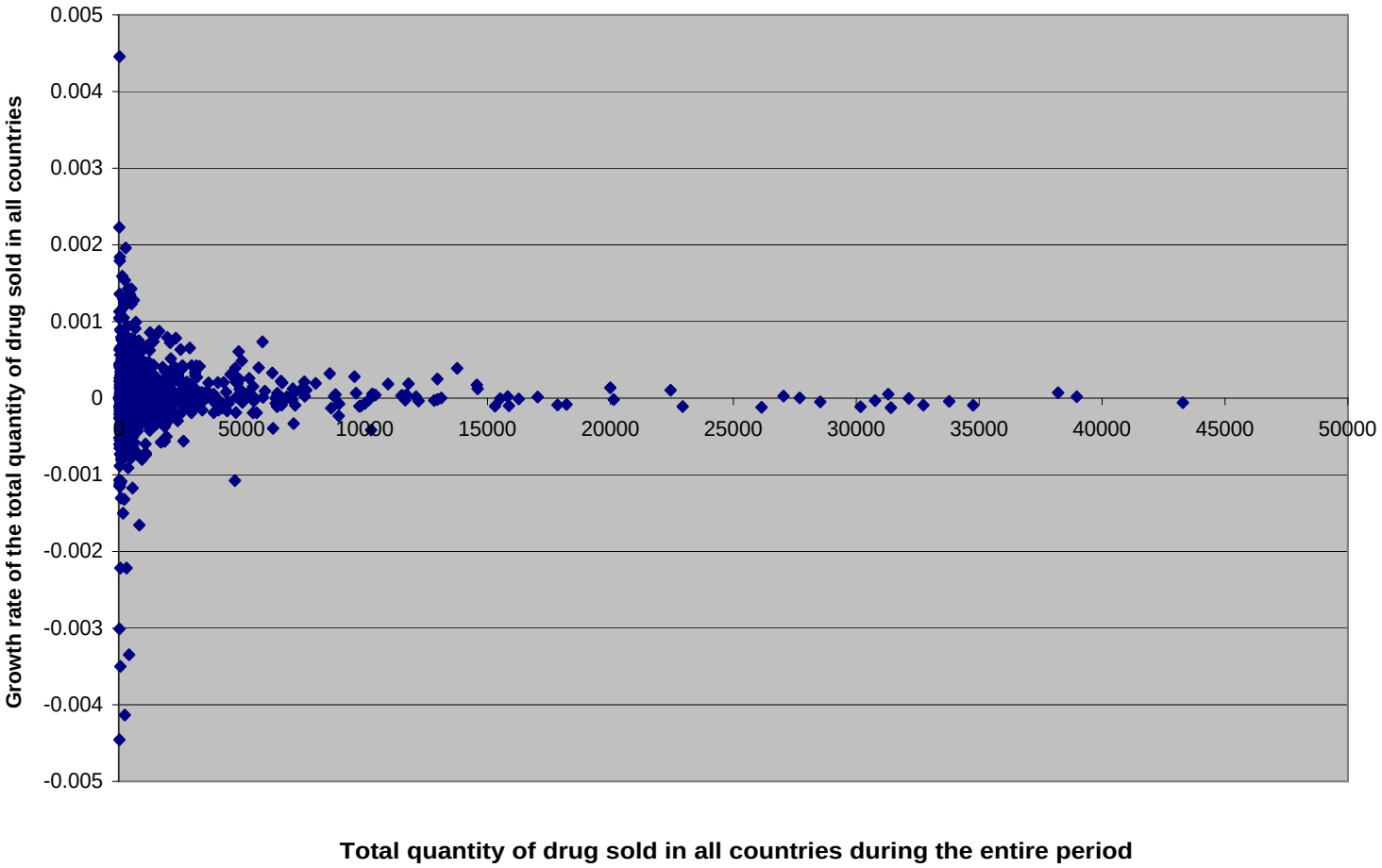
Figure 4
Relationship between total quantity of drug sold during the entire period and growth rate of the total quantity of drug sold in all countries



established.[6] We were able to determine the INN year of about half of the drugs in the sample. Table 3 provides descriptive statistics on both the full sample and the subset of drugs for which the INN year could be determined.

The estimation method described above is a two-step method. In step one, some variables are regressed on time trends to compute their growth rates. In step two, regressions involving these growth rates are estimated. An alternative (one-step) approach is to estimate the following model:

$$\ln Q_{.dt} = \beta \ln CV\_P_{.dt} + \gamma X_{.dt} + \alpha_d + \delta_t + \varepsilon_{.dt} \qquad (7)$$

Since eq. (7) includes both drug and period fixed effects, it is a difference-in-differences model. A positive and significant estimate of β would indicate that drugs with larger (percentage) increases in price dispersion (as measured by the coefficient of international price variation) tended to have larger (percentage) increases in output, controlling for the covariates. We adopt the two-step approach for several reasons. First, the two-step approach allows us to control for time-invariant covariates (e.g. drug vintage) which cannot be controlled for in the one-step approach. Second, estimation of eq. (6) is computationally burdensome, because one must allow for clustering of disturbances within drugs, and the number of drugs is quite large. Third, we estimated some models (those that excluded drug vintage) using both two-step and one-step approaches, and found that the results were quite similar.

Weighted least-squares estimates of eq. (3) are shown in Table 4. In the model in column 1, the only explanatory variable is CV_P', the growth rate of the (weighted) coefficient of (international) variation of the price. The coefficient is positive and highly significant (p-value < .0001), which indicates that drugs that had larger increases in international price dispersion had larger increases in total utilization. The model in column 2 also includes MEAN_P', the growth rate of the mean price. The coefficient on this variable is negative and highly significant (p-value < .0001). Under certain assumptions, the estimate of this coefficient (-0.379) could be interpreted as the price elasticity of demand. Controlling for MEAN_P' has very little effect on the CV_P' coefficient. The model in column 3 also includes INN_YEAR, the year in which the drug's International Nonproprietary Name was established, as a continuous variable. The coefficient on INN_YEAR is positive and significant, which indicates that newer drugs tend

[6] An INN is the official non-proprietary or generic name given to a pharmaceutical substance, as designated by the World Health Organization (WHO). The plethora of named proprietary preparations containing a given substance can lead to confusion about the identity of the active ingredient. INNs facilitate communication by providing a standard name for each substance. See http://en.wikipedia.org/wiki/International_Nonproprietary_Name and http://www.who.int/medicines/services/inn/en/.

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Table 3

Descriptive statistics

FREQ	_STAT_	Q'	CV_P'	MEAN_P'	inn_year
Full sample					
2599	N	1414	1414	1414	1184
2599	MIN	-1.626	-4.196	-1.373	1953
2599	MAX	1.626	2.332	0.844	2007
2599	MEAN	0.008	0.012	0.034	1966.53
2599	STD	3.264	4.270	2.483	426.444
2599	SUMWGT	2332423	2332423	2332423	1413695
Drugs with known INN year					
1184	N	746	746	746	1184
1184	MIN	-1.626	-4.196	-0.807	1953
1184	MAX	0.813	2.332	0.844	2007
1184	MEAN	0.021	0.014	0.025	1966.53
1184	STD	3.469	4.237	2.627	426.444
1184	SUMWGT	1388890	1388890	1388890	1413695

Table 4

Weighted least-squares estimates of eq. (3)

Column	1	2	3	4
CV_P’				
est	0.19062	0.17798	0.16045	0.10571
SE	0.02919	0.02796	0.02694	0.02789
t	6.53	6.37	5.96	3.79
p	<.0001	<.0001	<.0001	0.0002
MEAN_P’				
est		-0.37882	-0.25938	-0.3085
SE		0.0451	0.04585	0.04887
t		-8.40	-5.66	-6.31
p		<.0001	<.0001	<.0001
INN_YEAR (continuous)				
est			4.97E-06	
SE			6.25E-07	
t			7.96	
p			<.0001	
INN_YEAR (dummies)	no	no	no	yes
N	746	746	746	746
R-Sq	0.0542	0.1362	0.2042	0.37746

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to have higher rates of output growth. Including INN_YEAR as a continuous variable reduces the magnitude of the coefficient on MEAN_P' by about a third but has very little effect on the CV_P' coefficient. However, the relationship between drug vintage and output growth may be nonlinear and even non-monotonic. In column 4, we include INN_YEAR as a categorical variable rather than as a continuous variable.[7] This modification reduces the coefficient on CV_P' to just over half its value in column 1. However, the coefficient on CV_P' continues to be positive and highly statistically significant (p-value = .0002).

There is another, "nonparametric," way of characterizing the relationship between changes in price dispersion and changes in output. Suppose we group drugs into four quartiles, based on their value of CV_P'. Drugs in the lowest quartile are the 25% of drugs that had the lowest growth in price dispersion, etc. Then, we estimate the following equation via weighted least-squares:

$$Q'_d = \beta_1 \text{ LOWEST}_d + \beta_2 \text{ SECOND}_d + \beta_3 \text{ THIRD}_d + \beta_4 \text{ HIGHEST}_d + \gamma \text{ MEAN\_P'}_d + \text{INN\_YEAR dummies} + \varepsilon_d \quad (8)$$

where $\text{LOWEST}_d = 1$ if drug d is among the 25% of drugs that had the lowest growth in price dispersion, and otherwise equals zero; SECOND, THIRD, and HIGHEST are analogously defined. $(\beta_4 - \beta_1)$ may be interpreted as the difference between the output growth rates of drugs in the highest and lowest price dispersion growth quartiles. The estimated rates of output growth, by rate of increase of international price dispersion, are shown in Figure 5.[8] Mean output growth in the quartile of drugs with the largest increase in international price dispersion was 4.8%. Mean output growth in the quartile of drugs with the smallest increase in international price dispersion was -0.4%. The difference $(\beta_4 - \beta_1)$, which controls for mean price growth and drug vintage, is highly significant (p=value < .0001).

This evidence, which is based on data on a large number of drugs sold in 38 countries over almost a decade, indicates that, in general, increased price dispersion is associated with higher output growth, controlling for the growth in the mean price of the drug and the drug's vintage. The condition that economic theory indicates must be satisfied for price discrimination to increase social welfare appears to be satisfied in practice.

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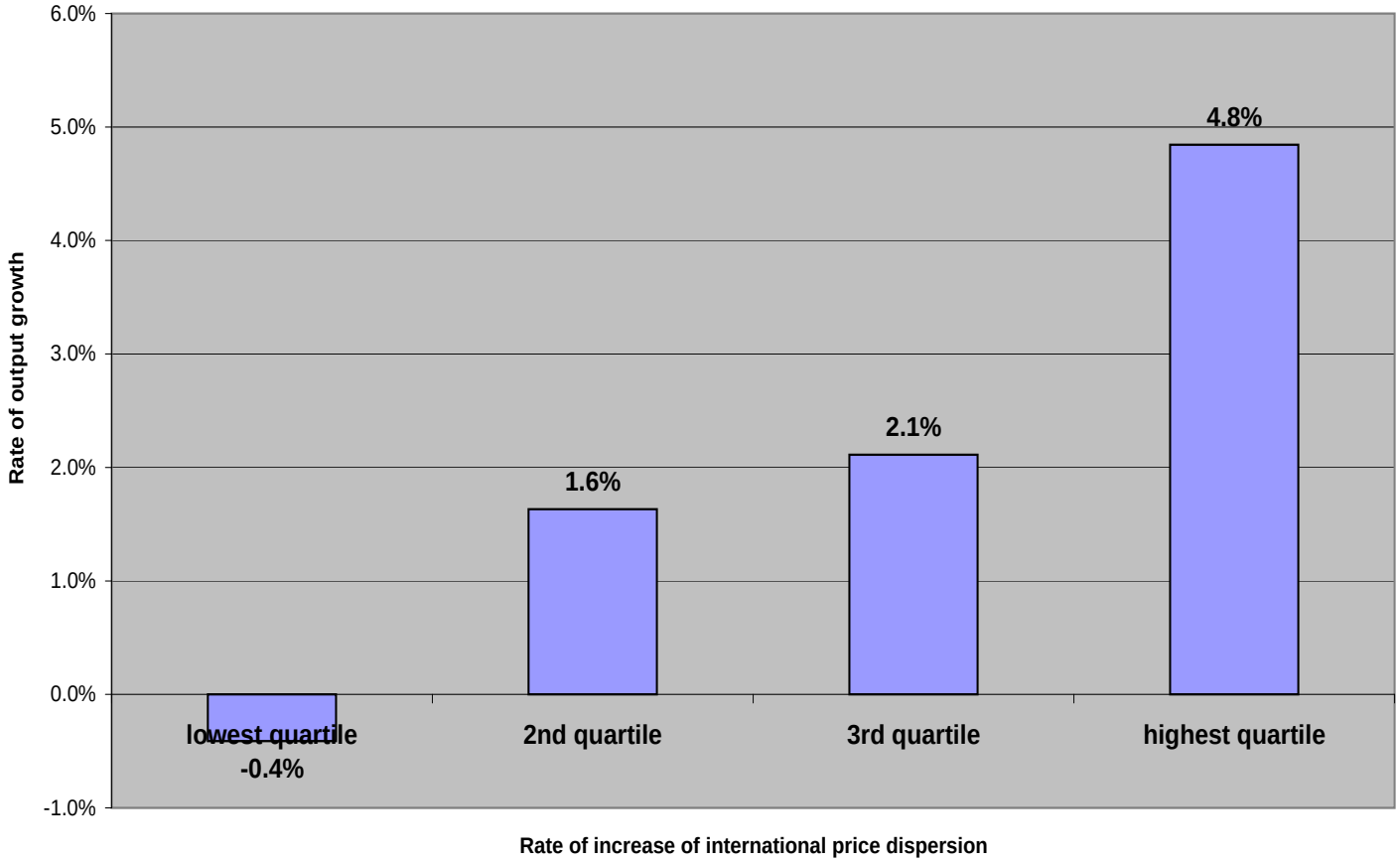
[7] A separate dummy variable is included for each value of INN_YEAR. In this model, we are essentially comparing drugs to other drugs of exactly the same vintage. To conserve space, we do not report the coefficients on the INN_YEAR dummy variables.

[8] The values plotted in Figure 5 are normalized to the average rate of output growth: $\beta_j - \Sigma_k \beta_k + .020$. The estimated β's are jointly highly significant (p=value < .0001).

Figure 5

Rate of output growth, by rate of increase of international price dispersion,
controlling for mean price growth and drug vintage



Note: there are about 187 drugs in each quartile.

Moreover, numerous studies have shown that increased prescription drug use results in improved health outcomes, or the converse: reductions in drug use result in worse health outcomes, such as higher risk of hospitalization and death. Hsu et al (2006) found that subjects whose benefits were capped had higher relative rates of visits to the emergency department, nonelective hospitalizations, and death. Mojtabai and Olfson (2003) found that poor adherence was associated with poorer health and higher rates of hospitalization. Stuart et al (2009) found that, for users of older oral antidiabetes agents, ACE inhibitors, ARBs, and statins, each additional prescription fill was associated with significantly lower risk of hospitalization, fewer hospital days, and lower Medicare spending. Tamblyn et al (2001) found that increased cost-sharing for prescription drugs in elderly persons and welfare recipients was followed by reductions in use of essential drugs and a higher rate of serious adverse events and emergency department visits associated with these reductions.

Effect of price discrimination on the number of markets served

Recall that Pigou (1920) demonstrated that price discrimination will reduce social welfare if all of the following conditions hold: (1) all markets are served at the non-discriminatory price; (2) surpluses obtained by all groups of consumers and profits have equal weight in social welfare; and (3) all demand functions are linear. Subsequent researchers showed that, even if the first two conditions hold, price discrimination can increase social welfare when the third condition is relaxed. In that case, price discrimination can increase total output. Cowan (2008) argues on theoretical grounds that "the conditions for discrimination to raise welfare are plausible." In the previous section, we presented evidence that increased international price discrimination is associated with higher output growth, which suggests that at least some demand curves are not linear, and therefore that price discrimination can increase social welfare.

In this section, we will argue that the first assumption underlying Pigou's theoretical demonstration of the inefficiency of price discrimination is also likely to be violated in pharmaceutical markets. Some markets that would not be served under uniform pricing will be served under price discrimination—even when all demand curves are linear—and this will increase social welfare. Therefore, in addition to increasing the output of existing products, the ability to engage in price discrimination is likely to increase the number of new products.[9]

One reason why some markets that would not be served under uniform pricing will be served under price discrimination is the existence of substantial

[9] Hausman and Mackie-Mason (1988) showed that "price discrimination can provide opportunities to serve new markets and to achieve scale and learning economies, both of which are important for many patented innovations."

fixed costs of production.[10] Cowan ignores the existence of fixed costs—he assumes that "a monopolist sells an identical product in two markets and has a constant marginal cost, $c \geq 0$," and zero fixed cost—presumably because he is interested in analyzing the consequences of violations of the third assumption above, when the other two assumptions are maintained.[11]

Due to fixed costs, a profit-maximizing firm may not develop and produce a product even though it would be socially desirable to do so (in the sense that the total benefits of production would exceed the total costs), because the firm pays all of the costs, but does not capture all of the benefits: it does not capture consumer surplus. This point can be easily demonstrated with a simple model of a single market. Suppose that this market can be described by a linear inverse demand curve ($P = a - b\ Q$, where P = price, Q = quantity, and a and b are positive constants) and a linear cost function ($C = F + m\ Q$, where C = total cost, F = fixed cost, m = marginal cost, and $0 \leq c < a$). One can show that investment is socially desirable as long as $F < (3\ a^2 / 8\ b)$. However, the firm will undertake the investment only if $F < (a^2 / 4\ b)$. If $(a^2 / 4\ b) < F < (3\ a^2 / 8\ b)$, the firm will not develop a socially desirable innovation. As F increases, the probability that the firm foregoes a socially desirable investment opportunity (due to its inability to capture consumer surplus) increases.

Price discrimination increases the firm's ability to capture consumer surplus. Hence, it reduces the probability that high fixed costs will prevent the firm from pursuing socially desirable investment opportunities.[12] This may be illustrated with a simple numerical example. Suppose there are two markets. The inverse demand curve of market 1 is $P_1 = 20 - Q_1$, the inverse demand curve of market 2 is $P_2 = 8 - Q_2$, and the firm's cost function is $C = F + (Q_1 + Q_2)$. It can be shown that if F = \$85, the firm would produce (and social welfare would be positive) if it could price discriminate, but not if it had to charge the same price in both markets. The equilibrium values of key variables under both pricing regimes are shown in the following table.

[10] Layson (1994) showed that factors other than fixed costs that favor market opening under price discrimination are: (1) a large market share for the strong market, (2) profit margins in the two markets that are far apart, and (3) concave rather than convex demand curves.

[11] Kaftal and Pal (2008) also assume zero fixed costs.

[12] Philipson and Jena (2006) estimated that innovators appropriated only 5% of the social surplus arising from the new HIV/AIDS therapies that entered the market from the late 1980's onwards.

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	Price discrimination	Uniform pricing
Q_1	9.5	12.5
Q_2	3.5	0.5
P_1	$10.50	$7.50
P_2	$ 4.50	$7.50
max. profit, if produce	$17.50	-$0.50
produce? (1 = yes, 0 = no)	1	0
profit	$17.50	$0.00
Consumer surplus in market 1	$45.12	$0.00
Consumer surplus in market 2	$6.12	$0.00
Social welfare	$68.75	$0.00

If fixed cost were $80 rather than $85, the firm would produce under both pricing regimes, and total consumer surplus and social welfare would be higher under uniform pricing (due to the assumption of linear demand curves).

In the presence of high fixed costs, social welfare can be higher under price discrimination than it would be under uniform pricing, even when demand curves are linear. One of the most important types of fixed cost is research and development (R&D) expense. According to the National Science Foundation, in 1997, "medical substances and devices firms had by far the highest combined R&D intensity at 11.8 percent,…well above the 4.2-percent average for all 500 top 1997 R&D spenders combined. The information and electronics sector ranked second in intensity at 7.0 percent."[13] The Tufts Center for the Study of Drug Development has estimated that the average cost to develop a new drug was $802 million in 2001. Schweitzer (2007, p. 8) argues that the pharmaceutical industry's "most differentiating characteristic is that it is particularly intensive in fixed costs."

The argument that, in the presence of high fixed costs, price discrimination can increase social welfare relies on two hypotheses: (1) the amount of R&D investment (and the number of drugs developed) is sensitive to expected profitability; and (2) pharmaceutical innovation has an important positive effect on social welfare. We conclude this section by briefly reviewing some empirical evidence about both of these hypotheses.

[13] R&D intensity is the ratio of R&D expenditure to sales. The pattern of 1997 R&D spending per employee was similar to that for R&D intensity, with medical substances and devices again the highest at $29,095 per employee. Information and electronics was second at $16,381. Combined, the top 500 1997 R&D firms spent $10,457 per employee.

A number of studies have shown that the amount of pharmaceutical R&D investment is influenced by factors that determine the expected profitability of investment. One important determinant of the expected profitability of drug development is market size (i.e. the number of people with a medical condition). Lichtenberg (2007) examined the relationship, across cancer sites (breast, prostate, colon, etc.), between cancer incidence and two different measures of pharmaceutical innovation: the number of distinct chemotherapy regimens for treating the cancer site, and the number of articles published in scientific journals pertaining to drug therapy for that cancer site. He found a significant positive relationship between the incidence of cancer and the number of chemotherapy regimens: a 10% increase in the number of cases was associated with a 5.3% increase in the number of chemotherapy regimens. He also found that there is more publication (presumably indicating more research and innovation) related to cancers with higher incidence. A 10% increase in cancer incidence is associated with a 6% increase in both the number of drug-therapy publications and non-drug-therapy publications.

Lichtenberg and Waldfogel (2009), using data on all diseases, provided additional evidence that market size matters in providing incentives for product development. They found that drugs are more likely to be prescribed to persons with more prevalent conditions. Just before the 1983 Orphan Drug Act, 45 percent of persons with a condition in the 25th percentile of prevalence were prescribed drugs, compared with 62 percent of persons with a condition in the 75th prevalence percentile. The Orphan Drug Act increased the incentive for firms to develop drugs for small populations, relative to the incentive for larger populations. As a result, there was a sharper growth in the drug consumption tendency in low-prevalence conditions than in more common conditions.

A second determinant of the expected profitability of drug development that has been shown to influence the amount of pharmaceutical R&D investment (or the number of drugs developed) is the expected price of a drug. Using industry-level time-series data for the period 1952-2001, Giaccotto, Santerre and Vernon (2005) estimated a significant positive (0.58) elasticity of pharmaceutical industry R&D with respect to the real price of pharmaceuticals. Abbott and Vernon's (2005) estimates suggested that the elasticity of innovation with respect to price may be somewhat higher (in the 0.67-1.33 range). They estimated that cutting prices by 40 to 50 percent in the U.S. would lead to the undertaking of between 30 to 60 percent fewer R&D projects (in early-stage development).

Two studies have shown that investment in pharmaceutical R&D depends on the "interaction" between quantity and price: increases in expected quantity have a larger effect on investment when the expected price is high, and vice versa. As shown in Figure 1, the price of drugs in the U.S. tends to be higher than it is in most other countries (although U.S. prices don't appear to be the highest). Civan

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and Maloney (2006) found that economic harm motivates the distribution of drug development across diseases, but it is economic harm in the United States alone that matters. Lichtenberg (2007) found that the number of drug-therapy publications is related to cancer incidence in more-developed countries, but not to incidence in less-developed countries.[14]

Since there is considerable empirical evidence that two important determinants of the expected profitability of investment—market size and (mean) expected price—have important effects on pharmaceutical R&D investment, it is quite plausible that the ability to price discriminate, which theoretically also influences expected profitability, also has an important effect on pharmaceutical innovation. A number of studies have provided evidence that the development and use of new drugs has resulted in significant increases in longevity and health, and that overall, new drugs have been highly cost-effective.

Some of these studies are about particular diseases, such as HIV/AIDS, cancer, and cardiovascular disease. Lichtenberg (2006) estimated that the HIV/AIDS drugs introduced during the mid-1990s increased the life expectancy of HIV/AIDS patients by at least 13 years, and that it also reduced their hospitalization rates. Lichtenberg (2008) examined the impact of pharmaceutical innovation and other factors on the survival of U.S. cancer patients during the period 1992-2003. He found that cancer survival rates increased more for those cancer sites that had the largest increases in the proportion of chemotherapy treatments that were "new" treatments, controlling for other types of medical innovation, cancer stage, and age at diagnosis. Chemotherapy innovation accounted for 74% of the increase in the 1-year observed survival rate for all cancer sites combined during the period 1992-2001. Lichtenberg (2009) found that OECD countries with larger increases in the share of cardiovascular drug doses that contained post-1995 ingredients had smaller increases in the cardiovascular disease hospital discharge rate during the period 1995-2003, controlling for the quantity of cardiovascular medications consumed per person, the use of other medical innovations (CT scanners & MRI units), potential risk factors (average consumption of calories, tobacco, and alcohol), and demographic variables (population size & age structure, income, and educational attainment). His estimates also indicated that use of newer cardiovascular drugs has reduced the age-adjusted cardiovascular mortality rate.

Other studies have examined the effect of pharmaceutical innovation *in general* (i.e., not innovation related to a specific disease) on longevity, health, and medical expenditure. Some of these studies have been based on patient-level data. For example, Lichtenberg (2010) analyzed micro data on virtually all of the

[14] He found that the number of *non-drug-therapy* publications is also related to cancer incidence in more-developed countries but not to incidence in less-developed countries.

drugs and diseases of over 500,000 people enrolled in Puerto Rico's Medicaid program to examine the impact of the vintage (original FDA approval year) of drugs used to treat a patient on the patient's 3-year probability of survival, controlling for demographic characteristics (age, sex, and region), utilization of medical services, and the nature and complexity of illness. He found that people using newer drugs during January-June 2000 were less likely to die by the end of 2002, conditional on the covariates. The estimated mortality rates were strictly declining with respect to drug vintage. For pre-1970 drugs, the estimated mortality rate was 4.4%. The mortality rates for 1970s, 1980s, and 1990s drugs were 3.6%, 3.0%, and 2.5%, respectively. The actual mortality rate is about 16% (3.7% vs. 4.4%) lower than it would have been if all of the drugs utilized in 2000 had been pre-1970 drugs.

Other studies have been based on aggregate data. Lichtenberg (2005) analyzed the impact of new drug launches on longevity during the period 1982–2001 using longitudinal, disease-level data from 52 countries. Under conservative assumptions, his estimates implied that the average annual increase in life expectancy of the entire population resulting from new drug launches is about one week, and that the incremental cost effectiveness ratio (new drug expenditure per person per year divided by the increase in life-years per person per year attributable to new drug launches) is about $6750—far lower than most estimates of the value of a statistical life-year.

Summary

Price discrimination, whereby a firm charges different prices to different groups of consumers for an identical good or service for reasons not related to costs, is an extremely common type of pricing strategy employed by virtually every business with some discretionary pricing power. The issue of whether price discrimination reduces or increases social welfare has been considered by economists since at least 1920. At that time, it was demonstrated that price discrimination will reduce social welfare if all of the following conditions hold: (1) all markets are served at the non-discriminatory price; (2) surpluses obtained by all groups of consumers and profits have equal weight in social welfare; and (3) all demand functions are linear.

Subsequent research has shown that if not all of the above conditions are satisfied, price discrimination can increase output and raise social welfare. In the early 1980s, economists proved that a necessary (but not a sufficient) condition for welfare to increase is that total output with discrimination exceeds the no-discrimination level. A recent study concluded that “the conditions for discrimination to raise welfare are plausible.”

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This paper had three main objectives. The first was to present international evidence and evidence from the USA about the relationship between income and drug prices. The second was to perform an empirical investigation of whether the necessary condition for price discrimination to increase welfare—that it increases total output—is satisfied in the case of international pharmaceutical prices. The third was to consider arguments and empirical evidence suggesting that the first assumption above—that all markets served under price discrimination are also served under uniform pricing—may be violated in the case of pharmaceutical markets.

We found that drug prices vary considerably across countries. Drug prices in the top 5 countries are almost five times as high as they are in the bottom five countries. Certain features of the drug price distribution were surprising. For example, according to our drug price index, the price of drugs in Mexico (which has the second-highest drug prices) is 24% higher than it is in the U.S. (which ranks sixth out of 38 countries). There is a highly significant positive correlation between per capita income and the drug price index: on average, the price of drugs is lower in low-income countries. However, there are large deviations from the regression line. Countries (particularly low-income countries) with similar levels of income pay vastly different prices for drugs.

Next we examined income-related price differentials in the U.S. When price was defined as total amount paid by all payers, price was again positively correlated with income, but the price differences were quite small: the price paid for prescriptions consumed by the poorest households is less than 3% lower than the price paid for prescriptions consumed by the richest households. When price is defined as the amount paid by the patient, there is an inverted-U-shaped relationship between income and price. People in the lowest income category pay 25% less than high income people (16% less if cases when the patient paid nothing are excluded), but people in the middle income category (whose income is 125-200% of the poverty line) pay 6% more than high income people (whose income exceeds 400% of the poverty line). This is presumably due to the fact that people in the middle of the income distribution are less likely to have prescription drug insurance than either high-income people (who have employer-based coverage) or people below the poverty line (who have Medicaid coverage).

We performed an empirical investigation of whether the necessary condition for price discrimination to increase welfare—that it increase total output—is satisfied in the case of international pharmaceutical prices, by analyzing the relationship across drugs between total output growth and growth in international price dispersion. Drugs that had larger increases in international price dispersion had larger increases in total utilization, controlling for the growth in the mean price of the drug and the drug's vintage. Mean output growth in the quartile of drugs with the largest increase in international price dispersion was

4.8%. Mean output growth in the quartile of drugs with the smallest increase in international price dispersion was -0.4%. The condition that economic theory indicates must be satisfied for price discrimination to increase social welfare appears to be satisfied in practice. Numerous studies have shown that increased prescription drug use results in improved health outcomes, or the converse: reductions in drug use result in worse health outcomes, such as higher risk of hospitalization and death.

In addition to increasing the output of existing products, the ability to engage in price discrimination is likely to increase the number of new products. We argued that, contrary to the assumptions of some theoretical models, some markets that would not be served under uniform pricing will be served under price discrimination. This would be the case whenever there are fixed production costs, and the pharmaceutical industry has much higher fixed costs (especially R&D expense) as a percentage of sales than most other industries. A number of studies have shown that the amount of pharmaceutical R&D investment is influenced by factors (other than the ability to price discriminate) that determine the expected profitability of investment. And a number of studies have provided evidence that the development and use of new drugs has resulted in significant increases in longevity and health, and that overall, new drugs have been highly cost-effective.

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