Pooled Procurement of Drugs in Low and Middle Income Countries*

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December 2020

Abstract

We use data from seven low and middle income countries with diverse drug procurement systems to assess the effect of centralized procurement on drug prices, and provide a theoretical mechanism that explains this effect. Our empirical analysis is based on exhaustive data on drug sales quantities and expenditures over three years for forty important molecules. We find that centralized procurement of drugs by the public sector leads to lower prices but that the induced price reduction is smaller when the supply side is more concentrated.

Keywords: Drugs, Procurement, Low and Middle Income Countries.

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*We gratefully acknowledge financial support from the Center for Global Development. We thank the editor, Robert M. Sauer, and four anonymous referees for very useful suggestions. We are particularly indebted to Mead Over for extensive and thoughtful comments. We are also grateful to Michael Borowitz, Kalipso Chalkidou, Hugo Molina, Susan Nazzaro, and Rachel Silverman for their comments, and Daniel Rosen for his initial help with the data. We also thank Christian Dale Abad, Celina Gacias, Beverly Lorraine Ho, Biljana Kozlovic, Martha de la Paz, and Tommy Wilkinson for helping us access information on centrally procured molecules in the Philippines, South Africa, and Serbia. The authors acknowledge funding from the Agence Nationale de la Recherche under grant ANR-17-EURE-0010 (Investissements d'Avenir program). The data was provided as part of an agreement TPA N 00076143.0 with IMS Health (IQVIA). The statements, findings, conclusions, views, and opinions contained and expressed herein are not necessarily those of IQVIA AG or any of its affiliated or subsidiary entities.

1 Introduction

Across low and middle income countries (LMICs), the prices of essential medicines, such as cancer treatments, HIV antiretrovirals, and antibiotics, display substantial variations, with the locally observed prices sometimes being many times higher than the lowest international reference level. For example, among a group of nine common molecules purchased by the countries included in our analysis, the observed mean price across countries varies by a factor of 16.[1] Even within countries, the data show variations of up to 300 percent across procurement channels. High prices, in turn, deplete already limited public health budgets and generate shortfalls in access, especially for the poorest and neediest part of the population.

Understanding these price variations and formulating policy recommendations for better and cheaper access to drugs in developing countries requires analyzing the market structure for drug procurement. It is likely that buyer fragmentation on the demand side – in particular, whether public procurement is centralized or not – and suppliers' degree of market power both matter in explaining the final prices of drugs.

In this paper, we analyze, both theoretically and empirically, the impact of procurement mechanisms and supply-side concentration on drug purchase prices in LMICs. LMICs use a variety of procurement mechanisms: centralized public procurement with or without central medical stores, decentralized public procurement, and private procurement. Across countries and therapeutic areas, the concentration of suppliers varies enormously, from single seller situations to highly competitive environments.

We first develop a model in which several firms offer differentiated products through a procurement process that can be either centralized or decentralized. We assume that public buyers are price-takers when buying in a decentralized manner, an appropriate assumption in the context of drug procurement in LMICs, but become non-price-takers when procurement is centralized, i.e., they are able to get together to bargain with suppliers. Under fairly general assumptions, we show that prices under centralized procurement are lower than prices under decentralized procurement.

We then use data from seven LMICs with diverse drug procurement systems to evaluate empirically which procurement mechanisms allow countries to access drugs at lower prices. Specifically, we use data from IMS Health (IQVIA) that exhaustively cover the sales quantities and expenditures of drugs for forty molecules at a finely disaggregated level by year and sector of purchase during the period 2015-2017. The countries included in the analysis are India (the State of Ker-

[1] See Section 4 for details.

ala), the Philippines, Senegal, Serbia, South Africa (a subset of three States: KwaZulu-Natal, North West and Eastern Cape), Tunisia, and Zambia.

The data displays rich variation in terms of the way drugs are procured, both across and within countries. For three of the countries in our sample (the Philippines, Serbia, and South Africa), the channels of drug procurement vary within specific therapeutic areas with, for example, specific HIV antiretrovirals being purchased centrally, while others are being purchased in a decentralized manner. We observe different purchase mechanisms being used simultaneously within molecules, mostly public and private, but also in some cases public centralized and decentralized. Finally, for over 95% of the observations in the data set, there is generic availability. As a result, there is potential competition at the product-level between different generic manufacturers within molecule groups.

Our empirical strategy first relies on exploiting, at each time, this within-molecule-country variation. The identification is possible because for a subset of molecule-country we observe purchases made simultaneously through the different channels (public centralized, public decentralized, private). There might also be within-molecule-country-year differences in prices at the product-level, because there are often several manufacturers offering different brands of the same generic molecule. This could drive differences in prices, through quality or if centralized procurement was targeting specific and cheaper formulations. We first address these concerns by adding product fixed effects. We also show that the price difference in favor of public centralized mechanisms does not arise from higher demand elasticity in the public sector.

In addition, we address the concern that the choice of procurement mechanisms, and in particular of which molecules are procured centrally, could still be related to unobservables not captured by the set of fixed effects. We use a selection correction procedure, inspired by a two-stage Heckman procedure, but slightly non-standard due to the overlap of the different buying procedures as the same molecule can be bought simultaneously through the different channels, private and public centralized or decentralized.

Finally, we estimate the role of suppliers' concentration by interacting the purchase mechanisms with within-therapeutic areas HHI indexes, which we instrument following classic methods in the industrial organization literature. The instruments for the HHI indexes in a given country are the HHI indexes of the same therapeutic area and year in other countries. These endogenous concentration indexes are correlated through characteristics common on the supply side, but their correlation does not come from local unobservables on the demand side.

Consistent with the model's predictions, our main finding is that centralized procurement of drugs allows the public sector to obtain much lower prices. These findings are robust to the

different steps described above. In our most stringent specification, with product fixed effect and selection correction, we find that centralized public procurement commands an average 15% price reduction. However, we also find that the reduction is smaller when the supply side is more concentrated. At the extreme, instrumenting the supply side concentration, we show that the price difference vanishes when public buyers face a supplier market with an HHI above 46%, which is approximately the 80th percentile of the distribution.

The economic literature addressing the issue of affordable access to drugs in developing countries has mostly considered the pricing question from a patent protection angle (e.g., Chaudhuri et al. (2006); Kyle and Qian (2014)). There, the trade-off appears to be between the potential costs of restrictive patent policies due to the higher prices resulting from monopolistic pricing policies, leading to the exclusion of a large number of poor and uninsured patients, and the potential benefits related to the faster diffusion of new drugs to markets enjoying stronger patent protection (Cockburn et al. (2016)). In a similar vein, Galasso and Shankerman (2020) show that the Medicines Patent Pool (MPP) increases licensing and, to a lesser extent, sales of HIV, hepatitis C and tuberculosis drugs in LMICs.

Those studies, however, have not addressed other important potential sources of friction in local drug markets, such as suppliers' market power and buyers' size, and the type of procurement mechanisms used by public buyers.[2] Our first main contribution is to show that these frictions matter, especially for the large set of off-patent drugs procured in developing countries. For molecules for which generics are available, the market structure and purchasing mechanisms are likely to be paramount in determining local prices.

One key mechanism that has been used to attempt to reduce unit purchase prices, which impact we test in this paper, is pooled procurement, whereby several buyers, either institutions in a single country or health agencies across countries, consolidate their purchases.[3]

The existing theoretical literature on the impact of pooled procurement on prices shows that, theoretically, prices can be either positively or negatively affected by the formation of a buyer group. For instance, in a setting with a single supplier, Chipty and Snyder (1999) and Inderst and Wey (2007) find that a buyer group leads to lower prices (for the group members) if the supplier's cost is convex, while it leads to higher prices if cost is concave.[4] Jeon and Menicucci (2019) also

[2]There is some evidence for developed countries. See for example Dubois et al. (2020), Ganapati and McKibbin (2019) for drugs, and Grennan (2013) for medical supplies.

[3]Pooled procurement arrangements may vary and include the joint acquisition of large quantities at a given time and the negotiation of contracts allowing for the supply of drugs over long periods.

[4]The reason behind this lies in the comparison between a marginal buyer's contribution to the surplus generated by trade and an infra-marginal buyer's contribution. If the latter is bigger (smaller) than the former, which is the case when the supplier's cost is convex, then a buyer group enables negotiation over a greater contribution.

find that the shape of suppliers' cost functions affects the impact of pooled procurement on prices in a model that extends the common agency setup (Bernheim and Whinston, 1986) to multiple suppliers selling to buyers who cannot commit to exclusive purchases. However, in contrast to earlier papers, they find that a buyer group has no effect on prices when cost is concave. They further show that when cost is convex, the effect on prices is negative whenever the Pareto-dominant equilibrium in terms of suppliers' payoffs is selected. In contrast, we find that a buyer group leads to lower prices regardless of the shape of the cost function.

Inderst and Montez (2019) uncover a new mechanism for why a buyer group may not always lead to lower prices. They consider a setting where multiple suppliers and buyers engage in bilateral bargaining, and prices are determined by buyers' ability to relocate purchases across suppliers and suppliers' ability to relocate sales across buyers (in case of a bilateral disagreement). In their model, an increase in the size of a buyer (due to the formation of a buyer group) increases the *mutual* dependency between that buyer and the suppliers by worsening their options to adjust trade in case of a disagreement. This change generates both positive and negative effects on prices and leads to an ambiguous prediction regarding the net impact of a buyer group on prices. A key difference between the model developed by Inderst and Montez (2019) and ours is that the former considers the effect of a change in the size of a buyer on prices keeping its bargaining power fixed, while the latter considers the effect of a switch from a regime in which buyers have no bargaining power to one in which they acquire bargaining power.

In practice, pooled drug procurement mechanisms have been implemented in the Eastern Caribbean Drug Service (ECDS) established in the late 1980s, which groups nine small island nations (see Huff-Rousselle and Burnett (1996)), the Gulf Cooperation Council group-purchasing program (Bahrain, Kuwait, Oman, Qatar, Saudi Arabia and UAE), and the Pan American Health Organization (PAHO) Strategic Fund, which groups seventeen countries for the purchase of vaccines. Similar arrangements have been used to procure antiretrovirals (ARV) drugs through the United States President's Emergency Plan for AIDS Relief (PEPFAR) and the Global Fund to Fight AIDS, Tuberculosis, and Malaria (Global Fund) (see, for example, WHO (2007), Dickens (2011), and Huff-Rousselle (2012)). Such arrangements also exist within countries, for example, in Brazil with the Price Registration System (PR), which allows several public agencies to organize a joint competitive bidding to purchase goods at uniform prices and terms (Barbosa and Fiuza (2011)).

Empirically, much of the evidence comes from the health literature and consists of mean price comparisons and qualitative reviews of procurement systems. Contributions analyzing price changes include Kim and Skordis-Worrall (2017), who find pooled procurement by the Global

Fund to reduce the price of Efavirenz by 16 to 19 percent in a differences-in-differences analysis of WHO Global price report mechanism (GPRM) data from 2004 to 2013, and Wirtz et al. (2009), who find no effect of procurement volume for twelve ARVs using the same data. Seidman and Atun (2017) provide a literature review of thirty-eight papers tracked through PubMed, Embase, CINAHL and the Health Economic Evaluation Database and provide several examples of contributions concluding to cost savings from pooled procurement. Danzon et al. (2015) focus on HIV/AIDS, tuberculosis, and malaria drugs in a cross-country cross-drug analysis for low and middle income countries. They find that higher per capita income and income inequality lead to higher prices, and that tendered procurement significantly reduces prices.[5]

These studies, however, rely on limited sets of drugs with specific characteristics, namely mostly those targeting infectious diseases such as HIV/AIDS, TB and Malaria, which are at the center of the attention of global health advocate and dedicated international organizations. We thus expect the particularities of these drugs to limit the external validity of such findings.

Our second main contribution is therefore to consider a much larger variety of drug classes, also including for example antibiotics, antihypertensives, and contraceptives. We do so while systematically addressing potential confounding factors related to the market structure of suppliers, an issue that appears to be key for drug procurement in LMICs, given the large potential market power accruing to large pharmaceutical firms in certain regions or types of drugs.

This paper is organized as follows. Section 2 describes the procurement institutions in our sample countries. Section 3 presents our theoretical model. Section 4 provides details about the data and descriptive statistics. Section 5 presents the econometric results, and Section 6 discusses policy implications and concludes. The proof of the theoretical result, additional descriptive statistics and robustness checks are presented in the Appendix.

2 Procurement Systems

Table 1 provides, for the seven countries included, information on socioeconomic characteristics (GDP per capita and population) and the structure of the health sector, including the size of the health market, the structure of health expenditures, and the type of data covered in this paper.

[5] A few papers in the economic literature have addressed pooled procurement, in particular through the lens of e-procurement. Bandiera et al. (2009) show that pooled procurement reduces inefficiencies ('passive waste') in the Italian context, although they do not focus on health procurement per se, and Barbosa and Fiuza (2011) show that the effect of pooled procurement contracts in Brazil varies depending on the composition of the pool of buyers. Specifically, they conclude that adding buyers with higher credit risk may drive up the price paid by the buyer group. In the context of the French bottled water industry, Molina (2020) shows that buyer alliances lead to a countervailing buyer power that reduces retail prices by roughly 7%.

As shown in the table, these countries' health sectors constitute a sample with relatively diverse characteristics. Level of development ranges from low income (Senegal and Zambia) to upper middle income (Serbia and South Africa), and both small and large countries population-wise are included. Accordingly, there is substantial variation, by a factor of 15, in the size of the health commodity market.

In terms of the structure of spending and the role of the public vs. private sector, the share of general government spending as a percentage of GDP varies from 1 to more than 5 percent. There are similarly large variations in the shares of private and out-of-pocket spending. Finally, at least one of the countries in the sample, Zambia, relies heavily on external aid (for approximately one-fourth of all spending).

Each procurement system has its particularities. For the purpose of this paper, and given the available data, we classify countries' procurement systems into the following groups.

- Countries with only private data available: these include Senegal and Kerala.
- Countries with both private and public data, for which:
  - The public sector purchases are fully centralized through a central medical store (CMS): this category includes Tunisia and Zambia.
  - The public sector operates through both centralized purchase mechanisms and decentralized purchases: this category covers the Philippines, Serbia, and South Africa.

Regarding the last group, Table 2 shows, for the molecules included in our analysis, which drugs are procured centrally by country. Importantly, all three countries present within-therapeutic area variation in terms of the coverage of centralized procedures, so for each of these countries, our sample of molecules includes for example some cancer drugs that are covered by these procedures and some that are not. Note that it is possible that molecules included in the central procurement process are also procured in a decentralized manner by specific health institutions.

Table 1: *Country Characteristics*

	Philippines	Serbia	Tunisia	Zambia	Kerala*	Senegal	South Africa
Country Characteristics							
Per capita GDP (US$)	3,580	5,310	3,690	1,360	2,400	950	5,490
Population (million)	101.7	7.1	11.3	16.1	36	15	55.3
Health Market Size							
Total health market size (million US$)	12908	3486	2909	1117	2279	541	26031
Total health commodity market size	1722.7	-	935.1	209.3	440.1	252.6	3099.4
Health Market Structure							
Total health expenditure (THE) as % of GDP	4.4	9.4	6.7	5.4	3.9	4	8.2
General govt health expenditure (GGHE) as % of GDP	1.4	5.4	3.8	2	1	1.3	4.4
GGHE as % of THE	31.4	57.7	56.3	36.6	25.6	31.9	53.5
Private as % of THE	68.1	41.9	43.3	39.2	73.6	56.5	44.0
External as % of THE	0.6	0.4	0.4	24.2	0.9	11.6	2.4
OOP as % of THE	53.5	40.6	39.8	37.6	65.1	44.0	7.7
Domestic tax rates (%) on drugs - VAT	12	8	6	0	12	0	14
Purchase Mechanisms							
Public – centralized – Central Medical Store	No	No	Yes	Yes	Unobserved	Unobserved	No
Public – centralized - Framework	Yes	Yes	No	No	No	No	Yes
Public – decentralized	Yes	Yes	No	No	No	No	Yes
Private	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: The health commodity market size indicator covers all public and private spending on pharmaceuticals, hospital consumables, diagnostic devices, long-lasting insecticide-treated nets, and biologics including vaccines. The health market size includes all health-related activities. THE = total health expenditure; GDP = gross domestic product; GGHE = general government health expenditure;
External = development assistance for health; GGHE + PRIVATE + EXTERNAL = THE; OOP = out-of-pocket.
* *Health market figures for Kerala are those of India. Sources: World Development Indicators (World Bank);*
World Health Organization, Countries Statistical Profiles; Health Policy Project, Countries Health Financing Profiles.

In Appendix A, we provide more details on the characteristics of the procurement systems of each of these groups of countries, focusing specifically on the nature of the purchase mechanisms in the public sector for the subset of countries for which data on public purchases are available.[6]

Table 2: *Molecules procured centrally by country*

		South Africa	Philippines	Serbia
Therapeutic area	Molecule			
Anemia	ERYTHROPOIETIN ALPHA	1	0	0
Antiulcerants	OMEPRAZOLE	1	0	1
Antihypertensives	BISOPROLOL	0	0	1
Antihypertensives	ENALAPRIL	1	1	1
Antibiotics	AMOXICILLIN	1	1	1
Antibiotics	AMPICILLIN	1	1	0
Antibiotics	CEFTRIAXONE	1	0	1
Antibiotics	AMOXICILLIN—CLAVULANIC ACID	1	0	1
Antiparasitics	ARTESUNATE	0	1	0
Antiparasitics	ARTEMETHER—LUMEFANTRINE	1	1	0
Antiparasitics	ALBENDAZOLE	1	0	0
Arthritis Immunosuppressants	DICLOFENAC	1	0	1
Asthma	COPD&SALBUTAMOL	1	0	1
Cancer	DOCETAXEL	0	1	0
Cancer	IMATINIB	0	0	0
Cancer	RITUXIMAB	1	0	1
Cancer	PACLITAXEL	0	1	1
Cancer	TRASTUZUMAB	0	1	1
Cancer	CAPECITABINE	1	0	0
Cancer	CISPLATIN	1	1	1
Contraceptives hormones	MEDROGESTONE	0	0	0
Contraceptives hormones	MEDROXYPROGESTERONE	1	1	0
Contraceptives hormones	ETHINYLESTRADIOL—LEVONORGESTREL	1	0	1
Contraceptives hormones	LEVONORGESTREL	1	0	0
Contraceptives hormones	ETHINYLESTRADIOL	0	0	0
Diabetes	INSULIN	1	1	1
Diabetes	METFORMIN	1	1	1
HIV Antiretrovirals	TENOFOVIR DISOPROXIL	1	1	1
HIV Antiretrovirals	EFAVIRENZ	1	1	1
HIV Antiretrovirals	LAMIVUDINE	1	1	1
HIV Antiretrovirals	SOFOSBUVIR	0	0	0
HIV Antiretrovirals	TENOFOVIR—LAMIVUDINE—EFAVIRENZ	0	1	0
Lipid regulators	SIMVASTATIN	1	1	1
Nervous system medications	DIAZEPAM	1	0	1
Pain Analgesics	PARACETAMOL	1	1	1
Tuberculosis	CIPROFLOXACIN	1	1	1
Tuberculosis	RIFAMPICIN	1	0	1
Vitamins and Minerals	RETINOL	1	0	0
Vitamins and Minerals	ZINC	1	1	0
Vitamins and Minerals	RETINOL, CHOLECALCIFEROL	0	0	0

Notes: 1 denotes molecules procured centrally. Sources: South Africa: Master Procurement Catalogue http://www.health.gov.za/index.php/component/phocadownload/category/196. The Philippines: DoH Matrix. Serbia: INNs lists A, A1, B, and C.

[6]Private sector procurement covers a large number of modalities and is quite fragmented. Depending on the country, it may include purchases by large hospitals or pharmacy chains, private wholesalers and retailers, private distributors, clinics, and pharmacies purchasing from domestic private sector distributors outside of framework agreements. While it may be the case that some of these buyers pool their procurement, it seems safe to assume that due to the fragmentation of the sector, most of the purchase can be considered as decentralized.

3 Theoretical Model

In this section, we study theoretically the effect of centralized procurement on prices. The existing literature on buyer groups typically assumes that buyers are *non-price-takers* in the absence of pooled procurement and remain so if they engage in pooled procurement.[7] By contrast, we provide a model in which buyers are price-takers under decentralized procurement and suppose that centralization allows them to become non-price-takers. Which modeling strategy is better depends on the specific environment one considers. In the case of large retailers forming buyer groups (which has received much attention in the literature), it is natural to assume that buyers are non-price-takers even in the absence of a buyer group. However, in our setting, i.e., drug procurement in LMICs, it seems reasonable to assume that buyers (e.g., pharmacies and hospitals) are price-takers if the system is fully decentralized.

Consider $N \geq 2$ firms producing differentiated goods and competing against each other in prices. Denote c_i the marginal cost of firm $i \in \{1, 2, ..., N\}$, $\boldsymbol{p} = (p_1, p_2, ..., p_N)$ the vector consisting of all the prices set by the N firms, and $D_i(\boldsymbol{p})$ the demand addressed to firm i. Moreover, denote $\boldsymbol{p}_{-i}$ the vector derived from $\boldsymbol{p}$ by removing firm i's price p_i. We assume that firm i's profit function is strictly concave in its own price and that its best-response function $R_i(\boldsymbol{p}_{-i})$ is increasing in each of its rivals' prices (i.e., prices are strategic complements). We suppose that a Nash equilibrium $\boldsymbol{p}^* = (p_1^*, p_2^*, ..., p_N^*)$ to the Bertrand game exists and is unique. When $N \geq 3$, we assume further that for each $K \in \{2, ..., N-1\}$ and for any $(p_{K+1}, ..., p_N)$, the Bertrand game derived from the original game by fixing the prices of firms $K+1, ..., N$ to $(p_{K+1}, ..., p_N)$ has a unique Nash equilibrium.

Procurement of the products can be either decentralized or centralized. We suppose that the Bertrand-Nash prices $\boldsymbol{p}^* = (p_1^*, p_2^*, ..., p_N^*)$ prevail under the decentralized regime. By contrast, under centralized procurement, we suppose that a single entity, say a governmental agency, negotiates prices by engaging in simultaneous Nash bargaining with the N firms. We assume that the governmental agency's objective function takes the general form $W(\boldsymbol{p})$ and is differentiable and decreasing over $[c_1, +\infty) \times [c_2, +\infty) \times ... \times [c_N, +\infty)$. For instance, $W(\boldsymbol{p})$ could be consumer surplus, social welfare, or coverage. Thus, the prices that arise under centralized procurement solve the following system of maximization programs:

$$\max_{p_i \geq c_i} \left[(p_i - c_i) D_i(p_i, \boldsymbol{p}_{-i}) \right]^{1-\alpha_i} \left[W(p_i, \boldsymbol{p}_{-i}) - W(\infty, \boldsymbol{p}_{-i}) \right]^{\alpha_i} \tag{1}$$

[7] See, for instance, Chipty and Snyder (1999), Inderst and Wey (2007), and Inderst and Montez (2019). A notable exception is Jeon and Menicucci (2019) where sellers are assumed to make a take-it-or-leave-it offer (of a non-linear tariff) to buyers both in the absence and the presence of a buyer group.

for $i = 1, 2, ..., N$, where $\alpha_i \in (0, 1]$ captures the bargaining power of the governmental agency in charge of centralized procurement vis-à-vis firm i. Note that the limiting case $\alpha_1 = \alpha_2 = ... = \alpha_N = 0$ correspond to the Bertrand-Nash equilibrium (i.e., the equilibrium that prevails under decentralized procurement). We assume that the solution to (1), which we denote by $\tilde{R}_i(\boldsymbol{p}_{-i})$, is unique for any $\boldsymbol{p}_{-i}$, and characterized by the corresponding first-order condition. Moreover, we assume that the vector of prices $\tilde{\boldsymbol{p}} = (\tilde{p}_1, \tilde{p}_2, ..., \tilde{p}_N)$ under centralized procurement, i.e., the vector solving the system of maximization programs above, exists and is unique.

When $N \geq 3$, we further extend the above assumptions on the outcome of the simultaneous bilateral negotiation game to the derived game in which the prices $(p_{K+1}, ..., p_N)$ are fixed while the prices $(p_1, ..., p_K)$ result from the maximization of the Nash products given by (1) for each $i = 1, 2, ..., K$.

The following proposition compares prices under decentralized procurement to those under centralized procurement.

Proposition 1. *Prices under centralized procurement are lower than prices under decentralized procurement.*

Proof. See Appendix. □

While this result is intuitive, it is not obvious because the strategic interaction between the N suppliers generates equilibrium effects that could, in principle, lead to an ambiguous impact of centralized procurement on equilibrium prices, despite the clear-cut effect of centralized procurement on the price of one product *given* the prices of the other products. We show, however, that in a fairly general setting, the equilibrium prices unambiguously decrease when one switches from a decentralized to a centralized procurement regime. Note that this result differs from the ambiguous finding in several papers considering that buyers have some bargaining power even when they act as individual buyers (e.g., Chipty and Snyder (1999), Inderst and Wey (2007), and Inderst and Montez (2019)).

Further, it is easy to see that Proposition 1 would still hold if marginal costs were strictly increasing or strictly decreasing. This result stands in sharp contrast to existing papers on buyer groups emphasizing the curvature of the cost function as a key determinant of the profitability of a buyer group (e.g., Chipty and Snyder (1999), Inderst and Wey (2007), and Jeon and Menicucci (2019)).

Interestingly, note that it is not necessary for the procurement of all products to be centralized for the result above to hold. Even if only a subset of products is centrally procured, the prices of *all* products will fall with respect to the decentralized regime. Thus, centralized procurement of

one or several drugs generates downward pressure on the prices of non-centrally procured drugs. The key intuition behind this result lies in the strategic complementarity between the prices of (imperfectly) substitutable products.[8]

A natural question that arises is how supply-side concentration affects the impact of centralized procurement on prices. In a setting with differentiated products such as ours, one way of changing supply-side concentration while leaving the set of available goods unchanged is to fix the number of goods and allow some firms to produce more than a single good (e.g., to produce a branded drug and a generic drug simultaneously).[9] Determining theoretically the (sign of the) impact of supply-side concentration on the price reduction resulting from centralized procurement raises two difficulties. First, we need to understand the (potential) relationship between the bargaining power parameters α_i and supply-side concentration, which would require developing a microfoundation for the parameters α_i that is out of the scope of the present paper.[10] Second, even if we make the (arguably strong) assumption that a change in supply-side concentration does not affect the bargaining power parameters α_i, we still face a source of ambiguity, namely the fact that an increase in supply-side concentration is likely to lead to higher prices under *both* centralized and decentralized procurement. This makes the theoretical impact of supply-side concentration on the price reduction resulting from centralized procurement unclear even if the parameters α_i remain unchanged.[11] The above discussion suggests that the impact of supply-side concentration on the price reduction resulting from centralized procurement should be approached empirically, which we do in Section 5.

4 Data and Descriptive Statistics

We use data on drug purchases from IMS Health (IQVIA), which provides exhaustive information on sales quantities and expenditures for 40 essential molecules across 16 therapeutic areas by country, year and sector of purchase.

The sample covers seven LMICs with diverse drug procurement systems: four middle income countries – the Philippines, three States in South Africa (KwaZulu-Natal, North West and Eastern

[8] Note that with complementary products, the centralized procurement of a subset of products would drive *up* the prices of the products outside that subset under the standard assumption that prices for complementary products are strategic substitutes.

[9] Alternatively, we could assume that some sellers are not active because of relatively high marginal costs, or assume that each of the differentiated goods could be produced by more than a single firm. Note that in the latter case, the price of a product sold by two or more distinct (symmetric) sellers would be driven to marginal cost of production under both the decentralized and centralized regime.

[10] Note that in the analysis of the effect of centralized procurement on prices, we were agnostic about the existence of such a relationship because it was irrelevant for the issue at hand.

[11] In our setting, using specific, instead of general, demand functions does not help resolve that ambiguity because it is difficult to obtain closed-form expressions for prices under centralized procurement.

Cape), Serbia, and Tunisia – and three low income countries –Senegal, Zambia, and the state of Kerala in India. The period covered is 2015-2017, with the exception of the Serbian data, which corresponds to 2013-2016. Finally, as described in section 2 above, we observe purchases from both the private and the public sector and whether these occur in a centralized or decentralized manner.

Table 3 lists the molecules included in the analysis and the different therapeutic areas to which they belong. This table also shows which molecules are purchased in which country. The heterogeneity in the mix of drugs procured across countries is likely related to the different needs of the respective populations, patent and regulatory policies, and supply-side factors, such as producers' marketing strategies.

Table 4 reports descriptive statistics by country and sector/channel of procurement. The table lists the number of molecules purchased and their mean price. It also shows the mean prices of the nine molecules that are purchased in all the countries for which we have data: Amoxicillin-clavulanic acid, Bisoprolol, Ciprofloxacin, Diclofenac, Enalapril, Metformin, Omeprazole, Salbutamol, and Simvastatin. The mean prices are the prices per standard unit obtained as the ratio of total US dollars expenses on that molecule to the total number of standard units of that molecule across the different brands and dosages.[12]

The comparison of mean prices shows considerable heterogeneity across countries and within countries across procurement channels. For example, for the nine common molecules, the average procurement cost per standard unit is \$0.11 in the Philippines public centralized channel but \$0.46 in the decentralized channel and \$0.77 in the private sector. In South Africa, the private sector pays much more than the public sector, but the difference between centralized and decentralized procurement is small. On the contrary, in Serbia, the private sector mean price is lower than that of the public sector. Additionally, and surprisingly, low income countries do not necessarily pay lower prices, as Senegal and Kerala pay much more than Tunisia and Serbia.

[12] A standard Unit (SU) is a standard IMS-derived measure of the number of doses and is measured differently depending on the formulation of the medicine, with one SU usually being equal to one tablet, one capsule, one suppository, one prefilled syringe/cartridge, pen, vial or ampule, one dose of an inhaled medicine or 5 ml of an oral syrup or suspension. The SUs of topical treatments (granules, powders, pellets, eye and ear preparations) are based on milliliters or grams. Note that SUs differ from WHO's Defined Daily Dose (DDD). Importantly for our analysis, SUs are consistent within countries over time.

Table 3: *List of molecules by country*

Area	Molecule	Kerala	Philippines	Senegal	Serbia	South Africa	Tunisia	Zambia
Anemia	ERYTHROPOIETIN ALPHA		X	X	X			
Antiulcerants	OMEPRAZOLE	X	X	X	X	X	X	X
Antihypertensives	BISOPROLOL	X	X	X	X	X	X	X
Antihypertensives	ENALAPRIL	X	X	X	X	X	X	X
Antibiotics	CEFTRIAXONE				X			
Antibiotics	AMOXICILLIN						X	
Antibiotics	AMPICILLIN		X	X	X		X	X
Antibiotics	AMOXICILLIN—CLAVULANIC ACID	X	X	X	X	X	X	X
Antiparasitics	ARTEMETHER—LUMEFANTRINE			X		X		X
Antiparasitics	ARTESUNATE	X		X				
Antiparasitics	ALBENDAZOLE	X	X	X		X	X	X
Arthritis Immunosuppressants	DICLOFENAC	X	X	X	X	X	X	X
Asthma / COPD	SALBUTAMOL	X	X	X	X	X	X	X
Cancer	CAPECITABINE				X			
Cancer	CISPLATIN		X	X	X	X	X	
Cancer	RITUXIMAB	X	X	X		X	X	
Cancer	DOCETAXEL				X			
Cancer	PACLITAXEL		X			X	X	X
Cancer	TRASTUZUMAB				X			
Cancer	IMATINIB		X		X	X	X	X
Contraceptives hormones	MEDROXYPROGESTERONE	X		X		X		X
Contraceptives hormones	MEDROGESTONE						X	
Contraceptives hormones	ETHINYLESTRADIOL—LEVONORGESTREL	X	X	X		X	X	X
Contraceptives hormones	LEVONORGESTREL						X	
Contraceptives hormones	ETHINYLESTRADIOL						X	
Diabetes	INSULIN	X		X	X	X	X	X
Diabetes	METFORMIN	X	X	X	X	X	X	X
HIV Antiretrovirals	TENOFOVIR—LAMIVUDINE—EFAVIRENZ	X				X		X
HIV Antiretrovirals	EFAVIRENZ						X	
HIV Antiretrovirals	LAMIVUDINE						X	
HIV Antiretrovirals	SOFOSBUVIR	X					X	
HIV Antiretrovirals	TENOFOVIR DISOPROXIL						X	
Lipid regulators	SIMVASTATIN	X	X	X	X	X	X	X
Nervous system medications	DIAZEPAM	X	X	X	X	X	X	X
Pain Analgesics	PARACETAMOL		X	X	X	X	X	X
Tuberculosis	CIPROFLOXACIN	X	X	X	X	X	X	X
Tuberculosis	RIFAMPICIN	X	X	X		X	X	
Vitamins and Minerals	ZINC			X			X	
Vitamins and Minerals	RETINOL		X	X		X	X	
Vitamins and Minerals	RETINOL, CHOLECALCIFEROL				X			

Note: Molecules included in the sample, by country and therapeutic area.

Table 4: *Country-level price statistics*

Country	Channel	Nb. of Molecules	Mean Price all molecules	Mean Price common molecules
Kerala	All	19	86.65	4.34
	Private	19	86.65	4.34
Philippines	All	21	6.72	.45
	Private	21	5.62	.77
	Public centralized	8	2.05	.11
	Public decentralized	21	9.40	.46
Senegal	All	24	30.94	3.93
	Private	24	30.94	3.93
Serbia	All	21	56.49	.13
	Private	21	58.20	.11
	Public centralized	15	71.16	.15
	Public decentralized	6	8.51	
South Africa	All	23	28.47	2.28
	Private	23	53.65	3.34
	Public centralized	19	12.79	1.68
	Public decentralized	3	14.81	1.83
Tunisia	All	30	21.36	.17
	Private	26	.38	.26
	Public centralized	30	39.28	.09
Zambia	All	20	2.71	.28
	Private	15	.97	.55
	Public centralized	17	4.04	.02

Note: Price in US$ by Standard Unit. Common molecules are AMOXICILLIN—CLAVULANIC ACID, BISOPROLOL, CIPROFLOXACIN, DICLOFENAC, ENALAPRIL, METFORMIN, OMEPRAZOLE, SALBUTAMOL, SIMVASTATIN. Mean price is unweighted by quantities.

Table 5 shows the coverage of our sample. In terms of expenses, the ATC3 categories included in our data represent between 19 and 35% of expenses on all ATC3 and between 11 and 52% of the expenses of the public sector.[13] Within the selected ATC3 categories, there is large variation in the share accounted for by the selected molecules, from South Africa, which has relatively low coverage, to Tunisia and Zambia, where most of the public expenses are included.

[13]The Anatomical Therapeutic Chemical (ATC) Classification System, controlled by the World Health Organization Collaborating Centre for Drug Statistics Methodology (WHOCC), divides active substances into groups at five different levels. The ATC3 level corresponds to the therapeutic/pharmacological subgroup.

Table 5: *Country-level statistics*

Country	Channel	Expenses All ATC3 (1000 $)	Expenses of Selected ATC3	Share of All (%)	Expenses of Selected Mol.	Share of selected ATC3 (%)
Kerala	All	60202227	13851093	23.0	1404918	10.1
	Private	60202227	13851093	23.0	1404918	10.1
Philippines	All	3634369	801021	22.0	365225	45.5
	Private	3406863	681674	20.0	272761	40.0
	Public	227533	119346	52.4	92389	77.4
Serbia	All	728293	179468	24.6	77148	42.9
	Private	369690	100733	27.2	34988	34.7
	Public	359057	78694	21.9	42216	53.6
South Africa	All	11394839	2114377	18.5	37209	1.7
	Private	7768901	1719998	22.1	19379	1.1
	Public	3626747	396451	10.9	17780	4.4
Tunisia	All	1052863	291687	27.7	198881	68.1
	Private	775158	253673	32.7	167657	66.0
	Public	277599	38014	13.6	31196	82.0
Zambia	All	360137	127114	35.2	122888	96.6
	Private	20990	1533	7.3	126	8.2
	Public	340703	129992	38.1	122878	94.5

Note: Values are in thousand US dollars. Selected ATCs are those of the 40 molecules studied. Exhaustive ATC3-level data on Senegal are missing.

An important aspect of our sample is that generics are available for most of the molecules. In fact, generic availability is the case for 33 out of 40 molecules, and over 95% of the observations in the data set.[14] For the molecules with generics available, it is possible to purchase different brands from different manufacturers and these are labeled as different products. The product differentiation will be useful, as it allows us to control for unobserved differences across these brands. Note however that in most cases our data is constituted of well-known drugs, so we don't expect significant differences in quality across different brands. In addition, the product dimension is directly related to suppliers' concentration, an issue to which we return below.

Table 6 shows the number of molecules purchased and the corresponding number of products and manufacturers. The table further breaks this information down by procurement sector and channel and shows that the public sector usually purchases fewer molecules and fewer products from fewer manufacturers.

[14]The exceptions are three cancer drugs, two contraceptives, one HIV antiretrovirals, and one anemia drug.

Table 6: *Country-level product and manufacturer statistics*

Country	Channel	Nb. of Molecules	Nb. of Products	Nb. of Manufacturers
Kerala	All	19	304	136
	Private	19	304	136
Philippines	All	21	526	263
	Private	21	488	255
	Public centralized	8	11	4
	Public decentralized	21	310	163
Senegal	All	24	117	76
	Private	24	117	76
Serbia	All	21	89	33
	Private	21	87	32
	Public centralized	15	68	28
	Public decentralized	6	15	11
South Africa	All	23	137	45
	Private	23	133	45
	Public centralized	19	79	32
	Public decentralized	3	8	7
Tunisia	All	30	167	77
	Private	26	152	68
	Public centralized	30	122	59
Zambia	All	20	53	30
	Private	15	40	30
	Public centralized	17	17	1

Note: Based on the sample molecules (IMS data). Yearly average over 2015-2017 for all countries except the Philippines (2013-2016). Private sector only for Kerala and Senegal.

Finally, Table 7 shows the mean HHI concentration index of manufacturers by therapeutic area, computed as the sum of squared market share (in quantities) of each manufacturer within the country, sector, year and therapeutic area.[15] The results show large variations in concentration and that many country-therapeutic areas display high provider concentrations. Note that the differences in concentration across therapeutic areas and molecules are closely related to the variation in the number of products, i.e., of different manufacturers of generic drugs. Indeed, in a simple regression, product dummies alone explain 75% of the variation in HHI in our sample.

[15]Table 14 in the Appendix provides similar information using the C1 concentration index instead.

Table 7: *Concentration by therapeutic area for each country (HHI)*

Area \ Country	Kerala	Philippines	Senegal	Serbia	South Africa	Tunisia	Zambia
Anemia		54.7 %	100.0 %	82.4 %			
Antiulcerants	28.8 %	32.8 %	12.0 %	63.0 %	50.9 %	36.6 %	77.9 %
Antihypertensives	46.6 %	49.6 %	58.6 %	30.8 %	66.0 %	64.2 %	86.7 %
Antibiotics	11.3 %	39.5 %	79.7 %	47.2 %	20.4 %	29.9 %	51.1 %
Antiparasitics	23.6 %	100.0 %	29.1 %		86.5 %	95.3 %	96.8 %
Arthritis Immunosuppressants	22.5 %	42.9 %	18.6 %	45.0 %	49.2 %	56.9 %	86.0 %
Asthma / COPD	74.7 %	45.9 %	92.8 %	74.5 %	69.2 %	91.9 %	100.0 %
Cancer	86.9 %	50.0 %	66.3 %	48.7 %	51.4 %	50.2 %	100.0 %
Contraceptives hormones	74.0 %	94.8 %	81.1 %		62.6 %	70.8 %	97.5 %
Diabetes	14.7 %	39.8 %	55.9 %	47.0 %	47.9 %	42.7 %	100.0 %
HIV Antiretrovirals	51.8 %				73.7 %	77.5 %	100.0 %
Lipid regulators	59.6 %	32.4 %	35.9 %	46.3 %	71.4 %	57.4 %	97.8 %
Nervous system medications	80.6 %	72.2 %	100.0 %	67.8 %	76.3 %	84.7 %	99.1 %
Pain Analgesics		46.3 %	87.1 %	31.2 %	37.5 %	17.9 %	100.0 %
Tuberculosis	28.8 %	47.3 %	21.5 %	40.2 %	39.5 %	49.8 %	78.1 %
Vitamins and Minerals		98.2 %	79.1 %	96.7 %	99.6 %	17.7 %	

Note: IMS data. Concentration (HHI) computed as the sum of squared market share (in quantities) of each manufacturer by country, year, and therapeutic area for the sample molecules. Means over 2015-2017 for all countries except the Philippines (2013-2016). Private sector only for Kerala and Senegal.

5 The Effects of Procurement Systems on Prices

We now turn to the econometric analysis of the effect of procurement systems on average prices. This section presents estimations at the product level (standard units).

5.1 Effects on Average Product Price

We start by estimating the following regression model for the log price:

$$log(p_{jcst}) = \alpha_{m(j)ct} + \theta_j + \lambda_s + \epsilon_{jcst} \tag{2}$$

where j is the product, $m(j)$ the corresponding molecule, c is the country, s is the procurement channel (private, public centralized or public decentralized) and t is the year. The parameter $\alpha_{m(j)ct}$ is a molecule-country-year specific effect that is sometimes restricted to be additively separable, as follows: $\alpha_{m(j)ct} = \alpha_{m(j)} + \alpha_c + \alpha_t$. The parameter θ_j is a product specific effect.

The parameter of interest is λ_s, which is a vector of dummies equal to one if at time t a specific product j is procured by the private, public centralized or public decentralized sectors respectively. Note that these dummies are not mutually exclusive. In a given country, a product can be procured under several modalities simultaneously.

The choice of procurement mechanism, and in particular the potential introduction of a centralized system in the public sector, is a molecule-level one, as shown in Table 2 above. We address this with by successively including molecule fixed effects, to absorb any fixed unobservable common across countries and specific to molecules that could be correlated with the chosen mix of procurement mechanisms, molecule-country fixed effects that absorb any fixed unobservable varying, for each molecule, at the country level and correlated with the procurement mechanisms and prices, and molecule-country-year fixed effects, to address the possibility that these unobservables also vary over time. Standard errors are clustered accordingly.

In addition, there might be unobservables related to the way authorities choose which specific drugs would be covered by public provision within a therapeutic area. The data shows that centralized procurement is more likely to happen for molecules that have generics formulations available. It is likely that the public sector uses centralized purchases when facing a larger number of suppliers, hence being able to take greater advantage of a stronger bargaining position. We address this by first controlling for the availability of generic formulation in all our specifications. We also control systematically for the number of molecules in the relevant therapeutic area, as substitutability across molecules for similar diseases may also reinforce the public sector bargaining position.

Columns (1) to (3) of Table 8 show these regressions using the log price of products as the dependent variable. Centralized procurement allows the public sector to obtain prices that are between 40 and 44% lower. This result is stable when including molecule-country-year fixed effects.

In column (4), we add product fixed effects. These absorb any additional unobserved variation related to differences in quality or formulation of similar molecules sold under different brands, although as stated above, we don't expect these to be meaningful for most of the generic drugs included in our sample. More importantly, we expect the product unobservables to capture most of the variation in supplier concentration across molecules. The coefficient for centralized procurement is reduced by 20%, but remains highly significant, showing that centralized procurement leads to prices that are around 33% lower.

The results are thus identified, at each time, by within-molecule-country, within-product variation. While the within product variation allows us to control to a large extent for differences across molecules in suppliers concentration, we would like to be able to estimate explicitly the impact of variations in concentration across drug and markets.

To do so, we drop the product fixed effects, and interact the procurement channel variables with the Herfindahl-Hirschman Index (HHI) of the suppliers in each therapeutic area, country

and year. Column (5) shows the results obtained by OLS. There is, however, an obvious problem of endogeneity of HHI indexes within this price equation. Since prices affect demand and market share, unobserved factors at the country-therapeutic area-year level likely affect both demands and prices and thus generate unobserved correlations with both price and market share.

We use the HHI indexes of the same therapeutic area and year in other countries as instruments for the HHI indexes in a given country. These instrumental variables are indeed correlated with the HHI index in the country because HHI indexes are correlated across countries through the supply-side market structures, which have common determinants across countries since most manufacturing firms are international and operate in many countries. HHI indexes covary across countries for many reasons including potential company mergers but also entry of firms in drug markets when patents expire or when new innovative products arrive.[16] On the other hand, instrumental variables defined in this way are likely to be uncorrelated with demand-side factors specific to local markets that explain the variation of the HHI indexes. Our strategy is similar to that of Dafny et al. (2012), who also uses an HHI index to examine the role of market concentration on health insurance premium in the US, and instrument it using the changes in local markets HHI due to the merger of two big insurance companies whose local pre-merger market shares vary.[17]

The first stage estimations are in Table 16 in the Appendix, Section C.5. Note that the instruments are strongly significant, with a joint F-test for the excluded instruments of 1577.14.

[16]Note that because the supply is global, the global market concentration for each specific molecule also matters. It enters the estimations through the molecule fixed effect terms.

[17]See among others Ackerberg et al. (2007) and Berry et al. (2019) for general discussion on how the industrial organization literature addresses endogeneity issues in market concentration upstream and downstream.

Table 8: *Product-level effect of procurement and market power on prices*

	(1)	(2)	(3)	(4)	(5)	(6)
Generic available	-0.2853	-0.8341	-0.8321	-1.1756***	-0.8355	-4.8246
	(0.1947)	(0.6629)	(0.6652)	(0.2905)	(0.6644)	(9633.5873)
Nb mol. purchased by Area	-0.2454***	-0.1186	-0.9002	-0.1109	-0.9287	0.2816
	(0.0362)	(0.1663)	(1.0667)	(0.5331)	(1.0661)	(606.0490)
Public decentralized	-0.0692	-0.0454	-0.0447	-0.0266	0.0924	-0.0846
	(0.0548)	(0.0463)	(0.0465)	(0.0224)	(0.0857)	(0.1904)
Public centralized	-0.3998***	-0.4366***	-0.4129***	-0.3335***	-0.1638	-1.3798***
	(0.0471)	(0.0411)	(0.0416)	(0.0195)	(0.0945)	(0.2881)
Public decentralized*HHI					0.0568	-0.2703
					(0.2175)	(0.5438)
Public centralized*HHI					-0.1104	1.5945***
					(0.1561)	(0.4474)
Private*HHI					0.4819***	-0.4022
					(0.1241)	(0.2261)
N	6126	6126	6126	6126	6126	6126
r2	.7900556	.8609983	.8647447	.9796621	.8651612	.8602534
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Molecule FE	Yes	Yes	Yes	Yes	Yes	Yes
Molecule×country FE	No	Yes	Yes	Yes	Yes	Yes
Molecule×country×year FE	No	No	Yes	Yes	Yes	Yes
Product FE	No	No	No	Yes	No	No
Method	OLS	OLS	OLS	OLS	OLS	2SLS

*Note: HHI index is the Herfindahl-Hirschman Index, whose support is [0,1]. 2SLS refers to the two-stage least-squares method, where variables interacted with the HHI index are instrumented. Instrumental variables are the interactions with the average HHI of the same area in other countries. ***, **, and * indicate significance at 1%, 5% and 10%, respectively.*

In column (6), we thus use a two-stage least-squares estimation where we instrument the interactions between procurement channels and suppliers' HHI with the instrument described above. We find that the price reduction obtained by the public sector using a centralized procurement system is significant, and that it is lower when the HHI index is higher, converging to zero when the HHI index reaches 87%. In our sample, 87% is close to the 95th percentile of country-therapeutic area HHI values. This shows that the supply-side market power of firms matters and that it may limit the ability of the public sector centralized procurement mechanism to induce lower prices. At the limit, the gains from centralized procurement vanish almost completely in very concentrated country-therapeutic area cases.

One can compute the combined effect confidence intervals, which show that the price difference across channels ceases to be significantly different for HHI values of approximately 0.6. In addition, note that neither private nor decentralized public procurement is affected much by HHI.

5.2 Robustness Checks

So far, our identification relies on the difference in prices across procurement mechanisms, and are obtained by exploiting variation within molecule-country-year and within product observations.

It relies crucially on the fact that for each country and time period in the sample a subset of molecules are procured simultaneously through different procurement channels.

Note that there is variation across countries in which drugs are centrally procured and which are not. If the same drugs were always centrally procured, we could be worried that there is something else specific to the drug delivery or related health care organization, for example market structure, that generates this choice and that is also affecting prices.

The previous empirical evidence is, however, not a complete proof of a causal relationship between procurement mechanisms and prices. Although the results rely on within molecule-country-year variation, the short time span of the sample does not allow us to observe changes in the procurement mechanisms used for the same molecules over time, for example the introduction of a centralized public procurement system where there was none previously, which could be interpreted as a natural experiment. Instead, we address these concerns in two ways.

5.2.1 Reduced-Form Demand

First, we test for potential confounding factors. In particular, we investigate whether the price differences across these mechanisms could result from differences in demand elasticities. Specifically, one concern is that the lower prices found for the centralized procurement channel may in fact reflect higher demand elasticities.

To assess this possibility, we estimate reduced-form elasticity relationships using our quantity data. Specifically, we use the following reduced-form demand equation:

$$\log(y_{jcst}) = \alpha_{m(j)ct} + \lambda_s + \beta_s \log(p_{jcst}) + \epsilon_{jcst} \tag{3}$$

where y_{jcst} is the aggregate demand of product j in country c, sector s and year t and the parameter $\alpha_{m(j)ct}$ is defined as above. The parameter β_s is the reduced-form price elasticity of demand, which is initially constrained to be identical across sectors and then allowed to vary.

This demand equation is likely to suffer from price endogeneity. Therefore, in columns (4) and (6) of Table 9, we implement 2SLS estimates using the mean prices of the same products in the same procurement channel of all other countries as instrumental variables. The logic, standard in the industrial organization literature, is that conditional on the set of fixed effects included, prices in other markets can be interpreted as supply shifters as they proxy for unobserved costs, and are hence valid instruments (Hausman (1996)).

Table 9 column (1) shows an average price elasticity of -0.72 when we do not instrument prices. When we instrument for price (column (2)), this average elasticity increases in magnitude to -0.88. When we allow the elasticity to differ across procurement mechanisms (column (3)) and

instrument for prices, as indicated above (column (4)), we find a price elasticity close to -1 (-0.97) for the private sector and the decentralized procurement public sector (-0.89) and a slightly lower value of approximately -0.72 for the centralized public sector.

These results support the idea that elasticities are not higher in absolute value in the public sector with centralized procurement and, therefore, that the difference in demand elasticities is unlikely to be a confounding factor explaining why prices are lower for centralized public procurement.

Table 9: *Reduced-form demand at the product level*

	(1)	(2)	(3)	(4)
log(price product)	-0.7246***	-0.8848***		
	(0.0433)	(0.2223)		
log price * Private			-0.6591***	-0.9725***
			(0.0455)	(0.2313)
log price * Public decentralized			-0.3698***	-0.8928***
			(0.0737)	(0.2461)
log price * Public centralized			-1.2099***	-0.7247**
			(0.0653)	(0.2546)
Generic available	-0.7317	-0.5430	-0.9690	-0.2055
	(2.1708)	(2.8421)	(2.1512)	(2.8756)
Public decentralized	-1.0514***	-0.9763***	-0.7748***	-0.9083***
	(0.1518)	(0.1501)	(0.1636)	(0.1919)
Public centralized	-0.0838	-0.1453	-0.7814***	0.1513
	(0.1370)	(0.1605)	(0.1548)	(0.2519)
N	6123	5886	6123	5886
r2	.3674599	.3680199	.3790775	.3587978
Country FE	Yes	Yes	Yes	Yes
Molecule×country×year FE	Yes	Yes	Yes	Yes
Method	OLS	2SLS	OLS	2SLS

*Note: 2SLS indicates that the two-stage least-squares prices in other markets are used as instrumental variables for prices. ***, **, and * indicate significance at 1%, 5% and 10%, respectively.*

5.2.2 Controlling for Selection

These controls do not completely rule out, however, the possibility that other unobservables may affect the procurement mechanism choice, i.e., whether the public sector procures in a centralized or decentralized way or both and the respective shares of each mechanism, and be also related to prices. In particular, we still need to rule out the case of potential time-varying unobservables affecting the procurement mechanism choices across countries for a given molecule even if variation in the procurement mechanisms mix within a country across molecules is not a problem because it is captured by the set of fixed effects above (molecule-country-year fixed effects).

We would for example have such an endogeneity issue if there were decision makers in the Philippines and South Africa deciding which procurement mechanism to use for Amoxicillin in a way correlated with time-varying factors that affect the price of this molecule in these two

countries. For example, changes in the market structure for specific molecules that generate potential additional savings could trigger an increase in the share of specific molecules, or the subset of products within a molecule class, being procured centrally in several countries at the same time.

To address this, we introduce a selection correction procedure.[18] We assume that the procurement mechanisms, which are not exclusive for each molecule i, are determined by the following probit models:

$$\begin{aligned}
\underbrace{Private_{jcst}}_{\in\{0,1\}} &= 1_{\{X_{jcst}\beta^1 - \varepsilon^1_{jcst} \geq 0\}} \\
\underbrace{Public_Decentralized_{jcst}}_{\in\{0,1\}} &= 1_{\{X_{jcst}\beta^2 - \varepsilon^2_{jcst} \geq 0\}} \\
\underbrace{Public_Centralized_{jcst}}_{\in\{0,1\}} &= 1_{\{X_{jcst}\beta^3 - \varepsilon^3_{jcst} \geq 0\}}
\end{aligned}$$

where j is the product, c is the country, s is the sector in the country (private, public centralized or public decentralized) and t is the year, and $\left(\varepsilon_{jcst}, \varepsilon^k_{it}\right) \overset{iid}{\hookrightarrow} N\left(\begin{array}{c} 0 \\ 0 \end{array}, \left[\begin{array}{cc} 1 & \rho_k \\ \rho_k & 1 \end{array}\right]\right)$,

or equivalently

$$\begin{pmatrix} \varepsilon_{jcst} \\ \varepsilon^1_{jcst} \\ \varepsilon^2_{jcst} \\ \varepsilon^3_{jcst} \end{pmatrix} \hookrightarrow N\left(\begin{array}{c} 0 \\ 0 \\ 0 \\ 0 \end{array}, \left[\begin{array}{cccc} 1 & \rho_1 & \rho_2 & \rho_3 \\ \rho_1 & 1 & 0 & 0 \\ \rho_2 & 0 & 1 & 0 \\ \rho_3 & 0 & 0 & 1 \end{array}\right]\right), \text{ with a joint c.d.f. denoted } \varphi(.,.,.,.).$$

This means for example that a molecule will be procured in both the private sector and under a decentralized public procurement mechanism if $Private_{jcst} = 1$ and $Public\_Decentralized_{jcst} = 1$

Now remark that the price equation is

$$\log(p_{jcst}) = \alpha_{m(j)ct} + \theta_j + \lambda_s + \varepsilon_{jcst}$$

where λ_s is a fixed effect for the procurement mechanism s, with
$s \in \{Private, Public\_Decentralized, Public\_Centralized\}$.

It is possible that $corr(\lambda_s, \varepsilon_{jcst}|X_{jcst}) \neq 0$, which then implies that $E\left(\varepsilon_{jcst}|s\right) \neq 0$. According to the distributional assumption above, $E\left(\varepsilon_{jcst}|s\right) = \Theta_s\left(z_1, z_2, z_3\right)$ for any s, allowing for the

[18] This appears better than a matching model. The three procurement mechanisms at play make standard binary treatment propensity score matching methods, which involves using multivalued treatment methods that are much more demanding in terms of identifying assumption, not applicable. For example, it would require overlap of propensity scores for each vector of treatment values (i.e., overlap of the probability distribution of being procured through a centralized mechanism or a decentralized one in the public sector and the one of being procured in the private sector).

derivation of each Θ_s. For example:

$E\left(\varepsilon_{jcst}|Private_{jcst} = Public\_Decentralized_{jcst} = Public\_Centralized_{jcst} = 1\right)$

$= E\left(\varepsilon_{jcst}|\varepsilon^1_{jcst} > z^1, \varepsilon^2_{jcst} > z^2, \varepsilon^3_{jcst} > z^3\right)$

$$= \int_{-\infty}^{+\infty}\int_{z^1}^{+\infty}\int_{z^2}^{+\infty}\int_{z^3}^{+\infty} \varepsilon_{jcst}\varphi\left(\varepsilon_{jcst}, \varepsilon^1_{jcst}, \varepsilon^2_{jcst}, \varepsilon^3_{jcst}\right) d\varepsilon^1_{jcst} d\varepsilon^2_{jcst} d\varepsilon^3_{jcst} d\varepsilon_{jcst} \equiv \Theta_s\left(z_1, z_2, z_3\right)$$

In practice we approximate each function $\Theta_s\left(z_1, z_2, z_3\right)$ using the probabilities that each sector is observed (equal to $\phi\left(X_{jcst}\beta^1\right)$, $\phi\left(X_{jcst}\beta^2\right)$, $\phi\left(X_{jcst}\beta^3\right)$ with ϕ the standard normal c.d.f.), which we use as control functions in equation (2).

The results in Table 10 show that controlling for selection in this way yields very similar outcomes to those found previously, thus reinforcing confidence in our results.

In column (4), the specification with molecule-country-year, and product fixed effects, centralized public procurement still commands a 15% price discount, significant at the 1% level, once we account for selection. In column (6), when instrumenting for the concentration index, the effect of centralized procurement is also negative and significant and it decreases a bit faster than in Table 8, reaching zero when the HHI index reaches 46%, i.e., approx. at the 80th percentile of the distribution. The fact that the threshold is lower when accounting for selection indicates that supplier concentration may account for some of the drivers of the adoption of centralized procurement.

Table 10: *Product-level effect of procurement and market power on prices with selection correction*

	(1)	(2)	(3)	(4)	(5)	(6)
Generic available	-0.3239	-0.1647	-0.6300	-1.0233**	-0.6154	-3.6464
	(0.1948)	(0.1636)	(0.8530)	(0.3689)	(0.8521)	(5294.8977)
Nb mol. purchased by Area	-0.2385***	0.0316	-0.6750	0.0987	-0.6569	1.7617
	(0.0363)	(0.1380)	(1.1913)	(0.5740)	(1.1931)	(1323.7244)
Public decentralized	-0.0788	-0.0524	-0.0522	-0.0279	0.0954	-0.0470
	(0.0550)	(0.0460)	(0.0476)	(0.0227)	(0.0859)	(0.2155)
Public centralized	-0.3980***	-0.3298***	-0.2347***	-0.1487***	0.0312	-1.2519***
	(0.0580)	(0.0496)	(0.0558)	(0.0246)	(0.1027)	(0.2666)
Public decentralized*HHI					0.1297	0.4959
					(0.3299)	(0.5956)
Public centralized*HHI					0.0252	2.7021***
					(0.3272)	(0.6558)
Private*HHI					0.6140*	0.5040
					(0.2664)	(0.3355)
N	6126	6126	6126	6126	6126	6126
r2	.7905575	.8607007	.8655506	.9803218	.8659437	.8607091
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Molecule FE	Yes	Yes	Yes	Yes	Yes	Yes
Molecule×country FE	No	Yes	Yes	Yes	Yes	Yes
Molecule×country×year FE	No	No	Yes	Yes	Yes	Yes
Product FE	No	No	No	Yes	No	No
Method	OLS	OLS	OLS	OLS	OLS	2SLS

*Note: HHI index is the Herfindahl-Hirschman Index, whose support is [0,1]. 2SLS refers to the two-stage least-squares method, where variables interacted with the HHI index are instrumented. Instrumental variables are the interactions with the average HHI of the same area in other countries. ***, **, and * indicate significance at 1%, 5% and 10%, respectively.*

5.2.3 Additional Robustness Checks

Table 17 in Section D.1 in the Appendix presents additional robustness checks, restricting the sample in two ways. First, it restricts the sample to the nine common molecules that are sold by all the country included in the analysis. Second, it restricts it to the three countries in which the public sector procures drugs through both centralized purchase mechanisms and decentralized purchases: the Philippines, Serbia, and South Africa. The results are again robust. When including both molecule-country-year and product fixed effects and the selection control functions, the results are in line with the one shown in Table 10: centralized public procurement commands a 14% price reduction.

Finally, in Appendix D.2, we include the results of estimations at the molecule level. While this higher level of aggregation reduces the sample from over six thousand observations to approximately one thousand, the results remain essentially unchanged.

6 Conclusion

We analyze the impact of public pooled procurement on drug purchase prices and study how this effect depends on drug market demand- and supply-side concentration in seven low and middle income countries (LMICs) using data on a large variety of essential drugs, most of them generic, covering 16 therapeutic areas.

Consistent with the predictions of a simple theoretical model, the empirical results show that centralized procurement systems allow public buyers to obtain significantly lower prices, by at least 15% even when we control for the possible choice of procurement mechanism by countries who can decide to procure a drug in different channels. Our results are identified using within molecule-country-year, and within product variation.

We then show that the price reduction effect of public centralized procurement depends on the concentration of firms on the supply side and their market power. Indeed, the effect vanishes when the public sector faces a high concentration of suppliers for a given product. Finally, we show that the results are robust to a variety of alternative specifications, including the use of selection control functions to address the potential endogeneity of the choice of procurement channels in the public sector.

The price reductions found in this paper may be driven by two complementary mechanisms. First, demand-side concentration may enhance public buyers' bargaining power, allowing them to extract lower prices, ceteris paribus. In addition, centralized procurers are likely to buy larger quantities, thus securing price discounts on larger orders. These two channels are hard to disentangle, as they occur simultaneously. Further research is needed to identify the nature of market interactions between buyers and sellers and to separate their effect from that of transaction size.

Finally, our results have important policy implications regarding supply-side concentration. Indeed, simple reduced form estimations of the impact of increasing supply-side competition show large potential increases in the quantity of drugs that public sectors could purchase for a given budget.

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A Country-level Procurement Systems

A.1 Fully Centralized Public Sector Purchases

A.1.1 Tunisia

Tunisia has a fully centralized procurement system. Law N90-105 entrusts the central medical store "Pharmacie Centrale de Tunisie" (PCT) with several key missions, among which:

- Sourcing and import monopoly of all drugs, chemicals, instruments, accessories, etc.
- Packaging and supply to wholesalers, laboratories and pharmacies.
- Informing physicians and pharmacists about all health related laws and regulations.

The Tunisian drug market is divided in two sectors, both with a predominance of local production: The hospital sector, with supply to the public structures exclusively provided by the PCT, and the retail sector, in which distribution is monopolized by the PCT only for the wholesale distribution of imported products.

A.1.2 Zambia

Healthcare in Zambia is provided both by the government and by faith-based organizations (FBO), with an important reliance on external donations to supply essential medicines to the population (see Table 1).

The Zambia Public Procurement Authority (ZPPA) is a centralized agency responsible for procurement of resources for all sectors, including the health sector.[19] The ZPPA handles all government expenditures above 500,000 ZMW or USD $100 000.[20] Some of ZPPA's responsibilities as lead of government procurement are delegated to an institutional tender committee in the Ministry of Health (MoH) called the Procurement and Supplies Unit. This unit handles smaller tenders and purchases that are valued under 500,000 ZMW. The MoH is instructed by the ZPPA to use the following three procurement strategies: international competitive bidding, limited international bidding, and national competitive bidding.

In addition, The Churches Health Association of Zambia is an FBO that procures health supplies, medical devices, and essential medicines for primary and secondary mission hospitals in Zambia.

[19] Republic of Zambia (2008) The Public Procurement Act, 2008. Zambia. Available at: https://www.zppa.org.zm/documents/20182/21181/Public_Procurement_Act_2008.PDF/2e47ad9f-ac97-404c-ace4-252314880ff6.

[20] Engstrand (2013) Report on the Healthcare Sector and Business Opportunities in Zambia. Available at: http://www.swecare.se/Portals/swecare/Documents/Report-on-the-Health-Care-Sector-and-Business-Opportunities-in-Zambia.pdf.

A.2 Mixed Centralized and Decentralized Public Sector Purchases

The Philippines, South Africa, and Serbia all present a mix of molecules procured centrally, and others not included in the central contracting process. This section describes briefly the main institutional features of their procurement systems.

A.2.1 Philippines

The central public health agency in the Philippines is the Department of Health (DoH), which provides national policy direction and regulation. Medicines procurement in the Philippines relies on both centralized and decentralized procedures: the DOH procures centrally, through annual purchase orders, but procurement is also done at all government levels, including retained hospitals, provinces, cities, municipalities and barangays (smallest administrative division in the Philippines).

The DOH procures medicines centrally for:

- National programs (single condition/small group health problems for which the objective focus is the short or medium term, such as tuberculosis).
- Medicines access programs (e.g., cancer).
- Emergencies and disasters.

The Government Procurement Reform Act of 2003 states that procurement should be undertaken through competitive bidding except under highly exceptional circumstances. In 2014, the DoH released a Drug Price Reference Index (DPRI) which made it mandatory that all public buyers adhere to a price ceiling when procuring drugs listed in Philippine National Drug Formulary (PNDF). However, some bid failures have been reported.

Table 2 shows the list of molecules that are included in centralized purchase, based on the DoH matrix of commodities. Note that drugs that are bought centrally and locally are not mutually exclusive. The DoH buys drugs according to what the program managers forecast and quantify in coordination with local facilities and hospitals, and these also have the freedom to procure the same drugs by themselves.

A.2.2 South Africa

South Africa has a national central tendering mechanism run by the National Treasury. Within that framework, provinces hold budgets and procure most of their commodities through 13 to 14 national contracts accounting for 90 percent of total spending. These contracts typically last for

2 to 3 years, with indicative volumes but no minimum commitments. HIV, TB, and Oncology are strategic focus areas for procurement. Historically, the South African government made a decision to not accept donations of commodities to favor local production. As a result, there are several local big players (Aspen, Cipla, Adcock Ingram), and many smaller ones, now making up approximately 20% of market value. Tendering practices also allow for local preference to encourage domestic firms, but in practice, these are often not able to compete on price, so imports remain very important. In order to sell products in South Africa, international manufacturers are required to contract any part of the supply chain (formulation, packaging, warehousing, and distribution) to a local player.

The Master Procurement Catalogue (MPC) provides all the medicines purchased through national tenders. The list of molecules covered by this arrangement is in Table 2.

A.2.3 Serbia

Serbia operates medicines and medical supplies procurement via a centralized procurement process managed by the Health Insurance Fund (HIF) on behalf of Healthcare Institutions (HCIs).[21] Article 48 of the Public Procurement Law attributes HIF contracting authority for good, services or works on behalf of medical institutions or health institutions within a Network Plan. It is also possible for HCIs to make orders for items, which are not on the list of approved medicines, however HIF is not obliged to provide funds for these so HCIs need to fund this themselves.

In 2014, the Republic of Serbia received a 29.1 million euros loan from the International Bank for Reconstruction and Development (IBRD) towards the cost of the Second Serbian Health Project (SSHP) which was scheduled to run from 2014-2019. The SSHP aim is to improve the efficiency of pharmaceutical and medical products procurement through the introduction of centralized procurement of drugs.

Medicines are procured centrally based on a list of medicines, which HIF has agreed to fund: lists A and A1, which include pharmaceuticals procured by brand name, and lists B and C, by molecule names. Based on this information, molecules included in the centralized procurement process are in in Table 2.

A.3 Countries With Only Private Sector Purchases

For Senegal and Kerala, we have access to only to private sector sales, which cover approximately 70% of the market for Senegal and 95% for Kerala.

[21] Limited (2012) Possible directions of increasing efficiency of Healthcare system in the Republic of Serbia.

B Proof of Proposition 1

We prove this proposition by induction, that is, we first show that the result holds for an environment with $N = 2$ firms, and then establish that the result holds for an oligopoly with N firms whenever it holds for an oligopoly with $N - 1$ firms.

Step 1. Let us show that the result holds for an industry with $N = 2$ firms. Consider first the decentralized system. The first-order conditions defining $R_1(.)$ and $R_2(.)$ are given, respectively, by

$$(p_1 - c_1)\frac{\partial D_1}{\partial p_1}(p_1, p_2) + D_1(p_1, p_2) = 0$$

and

$$(p_2 - c_2)\frac{\partial D_2}{\partial p_1}(p_1, p_2) + D_2(p_1, p_2) = 0$$

while the first-order conditions defining $\tilde{R}_1(.)$ and $\tilde{R}_2(.)$ are given, respectively, by

$$\begin{array}{c}(1-\alpha_1)\left[(p_1 - c_1) D_1(p_1, p_2)\right]^{-\alpha_1}\left[(p_1 - c_1)\frac{\partial D_1}{\partial p_1}(p_1, p_2) + D_1(p_1, p_2)\right]\left[W(p_1, p_2) - W(\infty, p_2)\right]^{\alpha_1} \\ + \left[(p_1 - c_1) D_1(p_1, p_2)\right]^{1-\alpha_1}\alpha_1\left[W(p_1, p_2) - W(\infty, p_2)\right]^{\alpha_1 - 1}\frac{\partial W}{\partial p_1} = 0\end{array}$$

and

$$\begin{array}{c}(1-\alpha_2)\left[(p_2 - c_2) D_2(p_1, p_2)\right]^{-\alpha_2}\left[p_2\frac{\partial D_2}{\partial p_1}(p_1, p_2) + D_2(p_1, p_2)\right]\left[W(p_1, p_2) - W(p_1, \infty)\right]^{\alpha_2} \\ + \left[(p_2 - c_2) D_2(p_1, p_2)\right]^{1-\alpha_2}\alpha_2\left[W(p_1, p_2) - W(p_1, \infty)\right]^{\alpha_2 - 1}\frac{\partial W}{\partial p_2} = 0.\end{array}$$

Using the fact that $W(.,.)$ is decreasing in both its arguments, we get that

$$\left[\tilde{R}_1(p_2) - c_1\right]\frac{\partial D_1}{\partial p_1}\left(\tilde{R}_1(p_2), p_2\right) + D_1\left(\tilde{R}_1(p_2), p_2\right) > \underbrace{\left[R_1(p_2) - c_1\right]\frac{\partial D_1}{\partial p_1}(R_1(p_2), p_2) + D_1(R_1(p_2), p_2)}_{=0}$$

and

$$\left[\tilde{R}_2(p_1) - c_2\right]\frac{\partial D_2}{\partial p_2}\left(p_1, \tilde{R}_2(p_1)\right) + D_2\left(p_1, \tilde{R}_2(p_1)\right) > \underbrace{\left[R_2(p_1) - c_2\right]\frac{\partial D_2}{\partial p_2}(p_1, R_2(p_1)) + D_1(p_1, R_2(p_1))}_{=0}.$$

This, combined with the concavity of each firm's profit function leads to

$$\tilde{R}_1(p_2) < R_1(p_2)$$

for any p_2 and

$$\tilde{R}_2(p_1) < R_2(p_1)$$

for any p_1.

Let us now compare the prices under the decentralized and centralized procurement systems. Note first that:

$$R_1 \circ R_2 \left(p_1^*\right) = p_1^*$$

Moreover, it must hold that

$$R_1 \circ R_2 \left(p_1\right) > p_1$$

for $p_1 < p_1^*$, and

$$R_1 \circ R_2 \left(p_1\right) < p_1$$

for $p_1 > p_1^*$. To see why, notice that if the latter conditions did not hold, the curves of $R_1(.)$ and $R_2(.)$ would intersect at least twice, which would violate the equilibrium uniqueness assumption.

Assume now that $\tilde{p}_1 \geq p_1^*$. This implies that

$$R_1 \circ R_2 \left(\tilde{p}_1\right) \leq \tilde{p}_1$$

However, since $\tilde{R}_1 \left(p_2\right) < R_1 \left(p_2\right)$ and $\tilde{R}_2 \left(p_1\right) < R_2 \left(p_1\right)$, we have that

$$\tilde{R}_1 \circ \tilde{R}_2(p_1) < R_1 \circ R_2 \left(p_1\right)$$

for any p_1, and in particular

$$\tilde{p}_1 = \tilde{R}_1 \circ \tilde{R}_2 \left(\tilde{p}_1\right) < R_1 \circ R_2 \left(\tilde{p}_1\right).$$

which leads to a contradiction.

Therefore, $\tilde{p}_1 < p_1^*$. Likewise, $\tilde{p}_2 < p_2^*$. This completes the proof for the case $N = 2$.

Step 2. Let us now assume that the result holds for an oligopoly with $N-1$ firms, and show that it holds for an oligopoly with N firms. Fixing p_N turns both the N-firm Bertrand game and the N-firm bilateral negotiation game into an $N-1$-firm Bertrand game and an $(N-1)$-firm bilateral negotiation game, respectively, with demand functions $\hat{D}_i$ defined by $\hat{D}_i \left(p_1, p_2, ..., p_{N-1}\right) = D_i \left(p_1, p_2, ..., p_N\right)$, and an objective function $\hat{W}$ defined by $\hat{W} \left(p_1, p_2, ..., p_{N-1}\right) = W \left(p_1, p_2, ..., p_N\right)$. Therefore, denoting $\left(R_1^* \left(p_N\right), R_2^* \left(p_N\right), ..., R_{N-1}^* \left(p_N\right)\right)$ the Nash equilibrium of the Bertrand game and where p_N is fixed, and $\left(\tilde{R}_1^* \left(p_N\right), \tilde{R}_2^* \left(p_N\right), ..., \tilde{R}_{N-1}^* \left(p_N\right)\right)$ the prices under centralized procurement when p_N is fixed, we have that

$$\tilde{R}_i^* \left(p_N\right) < R_i^* \left(p_N\right)$$

for any $i \in \{1, 2, ..., N\}$.

Note that p_N^* satisfies the following fixed point property.

$$p_N^* = R_N\left(R_1^*\left(p_N^*\right), R_2^*\left(p_N^*\right), ..., R_{N-1}^*\left(p_N^*\right)\right)$$

Moreover, it must hold that

$$R_N\left(R_1^*\left(p_N^*\right), R_2^*\left(p_N^*\right), ..., R_{N-1}^*\left(p_N^*\right)\right) > p_N$$

for any $p_N < p_N^*$ and

$$R_N\left(R_1^*\left(p_N^*\right), R_2^*\left(p_N^*\right), ..., R_{N-1}^*\left(p_N^*\right)\right) < p_N$$

for any $p_N > p_N^*$; otherwise, the uniqueness of the Nash equilibrium $\boldsymbol{p}^*$ would be violated.

Let us now assume that $\tilde{p}_N \geq p_N^*$ and show that this leads to contradiction. From $\tilde{p}_N \geq p_N^*$ and the above observation it then follows that

$$R_N\left(R_1^*\left(\tilde{p}_N\right), R_2^*\left(\tilde{p}_N\right), ..., R_{N-1}^*\left(\tilde{p}_N\right)\right) < \tilde{p}_N.$$

Moreover,

$$\tilde{R}_N\left(p_1, ..., p_{N-1}\right) < R_N\left(p_1, ..., p_{N-1}\right)$$

for any $p_1, ..., p_{N-1}$ (this results from a comparison of the FOCs defining $R_N\left(p_1, ..., p_{N-1}\right)$ and $\tilde{R}_N\left(p_1, ..., p_{N-1}\right)$ similar to the one we performed in the duopoly case). This, combined with the facts that $\tilde{R}_i^*\left(p_N\right) < R_i^*\left(p_N\right)$ and $R_i^*(.)$ is increasing (by strategic complementarity) for $i = 1, .., N-1$, leads to

$$\begin{aligned}\tilde{R}_N\left(\tilde{R}_1^*\left(\tilde{p}_N\right), \tilde{R}_2^*\left(\tilde{p}_N\right), ..., \tilde{R}_{N-1}^*\left(\tilde{p}_N\right)\right) &< R_N\left(\tilde{R}_1^*\left(\tilde{p}_N\right), \tilde{R}_2^*\left(\tilde{p}_N\right), ..., \tilde{R}_{N-1}^*\left(\tilde{p}_N\right)\right) \\ &< R_N\left(R_1^*\left(\tilde{p}_N\right), R_2^*\left(\tilde{p}_N\right), ..., R_{N-1}^*\left(\tilde{p}_N\right)\right)\end{aligned}$$

Since $\tilde{R}_N\left(\tilde{R}_1^*\left(\tilde{p}_N\right), \tilde{R}_2^*\left(\tilde{p}_N\right), ..., \tilde{R}_{N-1}^*\left(\tilde{p}_N\right)\right) = \tilde{p}_N$ we get that

$$\tilde{p}_N < R_N\left(R_1^*\left(\tilde{p}_N\right), R_2^*\left(\tilde{p}_N\right), ..., R_{N-1}^*\left(\tilde{p}_N\right)\right)$$

which leads to a contradiction.

Hence, $\tilde{p}_N < p_N^*$. Then, it follows that

$$R_i^*(\tilde{p}_N) < R_i^*(p_N^*)$$

for any $i = 1, ..., N-1$ (because $R_i^*(.)$ is increasing). This, combined with the fact that $\tilde{R}_i^*\left(\tilde{p}_N\right) < R_i^*\left(\tilde{p}_N\right)$ yields

$$\tilde{p}_i = \tilde{R}_i^*\left(\tilde{p}_N\right) < R_i^*(p_N^*) = p_i^*$$

for any $i = 1, ..., N-1$. This completes the proof.

C Additional Tables

C.1 Country-level Expenditure Shares

Table 11 shows the sample relative shares of public and private purchases by country.

Table 11: *Country-level expenditure statistics*

Country	Channel	Expenses (US$)	Expenses Share	Quantity Share
Kerala	All	1405081814		
	Private	1405081814	100 %	100 %
Philippines	All	365435032		
	Private	272765024	74.64 %	88.39 %
	Public centralized	18725270	5.12 %	8.35 %
	Public decentralized	73944732	20.23 %	3.25 %
Senegal	All	7106454		
	Private	7106454	100 %	100 %
Serbia	All	77128992		
	Private	34929636	45.28 %	59.70 %
	Public centralized	39531507	51.25 %	40.01 %
	Public decentralized	2667852	3.45 %	.27 %
SouthAfrica	All	101292416		
	Private	80913947	79.88 %	61.41 %
	Public centralized	20350720	20.09 %	38.58 %
	Public decentralized	27752	.02 %	.00 %
Tunisia	All	198926800		
	Private	167732000	84.31 %	71.52 %
	Public centralized	31194800	15.68 %	28.47 %
Zambia	All	121784771		
	Private	119796	.09 %	.15 %
	Public centralized	121664974	99.90 %	99.84 %

Note: IMS data. Share of total sample expenditures by sector and channel. Means over 2015-2017 for all countries except the Philippines (2013-2016). Private sector only for Kerala and Senegal.

C.2 Therapeutic Area Expenditure Shares

Tables 12 and 13 provide additional descriptive statistics for the selected therapeutic areas and molecules included in our analysis. Table 12 details the distribution of country-level expenditures for the molecules included in our analysis, showing that it provides relatively exhaustive coverage of therapeutic areas for the countries in the sample. Table 13 provides a benchmark consisting of the same information for all molecules in these categories.

Table 12: *Therapeutic area expenditure shares by country*

Area \ Country	Kerala	Philippines	Senegal	Serbia	South Africa	Tunisia	Zambia
Anemia		5.79 %		1.17 %			
Antiulcerants	7.18 %	8.31 %	27.14 %	1.38 %	19.94 %	6.77 %	.01 %
Antihypertensives	5.59 %	2.40 %	.10 %	20.45 %	9.12 %	2.99 %	
Antibiotics	42.27 %	13.70 %	6.96 %	7.66 %	2.57 %	39.00 %	.05 %
Antiparasitics	2.24 %	4.48 %	26.93 %		10.03 %	.73 %	14.51 %
Arthritis Immunosuppressants	1.40 %	1.68 %	6.58 %	12.09 %	15.22 %	1.88 %	.02 %
Asthma / COPD	5.15 %	7.80 %	7.57 %	1.62 %	6.83 %	1.48 %	.05 %
Cancer	.36 %	2.70 %	.15 %	19.98 %	8.49 %	7.63 %	.06 %
Contraceptives hormones	1.56 %	12.40 %	.72 %		2.13 %	2.43 %	2.59 %
Diabetes	27.68 %	10.12 %	6.92 %	21.00 %	9.79 %	7.81 %	.20 %
HIV Antiretrovirals	1.12 %				3.20 %	.42 %	82.35 %
Lipid regulators	.42 %	5.36 %	1.16 %	1.35 %	4.55 %	1.27 %	
Nervous system medications	.23 %	.18 %	.76 %	3.98 %	.28 %	.02 %	
Pain Analgesics		20.00 %	5.86 %	5.65 %	4.57 %	21.51 %	.08 %
Tuberculosis	4.74 %	4.69 %	8.86 %	3.48 %	3.16 %	1.54 %	
Vitamins and Minerals		.30 %	.21 %	.13 %	.04 %	4.44 %	

Note: Based on the sample molecules (IMS data). Yearly average over 2015-2017 for all countries except the Philippines (2013-2016). Private sector only for Kerala and Senegal.

Table 13: *Therapeutic Area Expenditure Shares by Country*

Area \ Country	Kerala	Philippines	Serbia	South Africa	Tunisia	Zambia
Anemia	2.51 %	3.93 %	1.70 %	1.25 %	1.61 %	.29 %
Antiulcerants	7.40 %	3.14 %	3.44 %	4.53 %	5.05 %	.13 %
Antihypertensives	7.78 %	14.94 %	18.41 %	8.87 %	12.94 %	.44 %
Antibiotics	17.30 %	18.14 %	7.97 %	12.64 %	20.27 %	6.11 %
Antiparasitics	.57 %	.20 %	.01 %	2.81 %	.39 %	5.83 %
Arthritis Immunosuppressants	5.16 %	5.32 %	8.48 %	5.93 %	8.34 %	.83 %
Asthma / COPD	8.89 %	4.90 %	6.73 %	4.23 %	3.79 %	.10 %
Cancer	.66 %	4.07 %	13.12 %	3.19 %	13.57 %	1.71 %
Contraceptives hormones	4.90 %	3.67 %	4.03 %	5.35 %	3.99 %	3.69 %
Diabetes	20.40 %	8.43 %	9.97 %	5.80 %	6.90 %	.22 %
HIV Antiretrovirals	.08 %	.01 %	2.03 %	9.14 %	.03 %	44.82 %
Lipid regulators	6.76 %	3.97 %	2.63 %	2.05 %	3.13 %	.05 %
Nervous system medications	6.11 %	3.17 %	11.09 %	7.68 %	6.81 %	.12 %
Pain Analgesics	2.51 %	6.04 %	4.31 %	8.86 %	6.74 %	1.21 %
Tuberculosis	.41 %	1.72 %	.01 %	2.81 %	.46 %	.54 %
Vitamins and Minerals	7.57 %	13.92 %	1.36 %	5.61 %	3.29 %	.21 %
Other	.92 %	4.36 %	4.62 %	9.17 %	2.60 %	33.62 %

Note: Based on all molecules (IMS data). Means over 2015-2017 for all countries except Philippines (2013-2016). Private sector only for Kerala and Senegal.

C.3 Concentration Index (C1)

Table 14: *Concentration by Area for each Country (C1)*

Area \ Country	Kerala	Philippines	Senegal	Serbia	South Africa	Tunisia	Zambia
Anemia		66.4 %	100.0 %	88.1 %			
Antiulcerants	44.4 %	44.0 %	18.4 %	72.1 %	61.4 %	50.4 %	81.3 %
Antihypertensives	62.2 %	62.2 %	69.6 %	43.7 %	76.5 %	75.1 %	91.7 %
Antibiotics	21.9 %	51.9 %	88.3 %	63.2 %	29.0 %	44.5 %	61.9 %
Antiparasitics	33.1 %	100.0 %	40.0 %		91.8 %	97.5 %	98.2 %
Arthritis Immunosuppressants	37.4 %	57.5 %	31.3 %	57.9 %	61.6 %	63.1 %	90.6 %
Asthma / COPD	84.8 %	62.9 %	96.2 %	84.0 %	78.9 %	95.7 %	100.0 %
Cancer	90.6 %	61.7 %	76.0 %	58.8 %	65.0 %	64.4 %	100.0 %
Contraceptives hormones	84.4 %	97.2 %	87.3 %		72.5 %	80.7 %	98.7 %
Diabetes	27.3 %	51.5 %	72.4 %	61.0 %	59.8 %	56.0 %	100.0 %
HIV Antiretrovirals	64.7 %				82.2 %	84.4 %	100.0 %
Lipid regulators	74.1 %	46.7 %	46.4 %	59.8 %	81.2 %	70.3 %	98.8 %
Nervous system medications	89.1 %	78.2 %	100.0 %	78.2 %	83.3 %	91.4 %	99.5 %
Pain Analgesics		55.0 %	93.2 %	40.6 %	50.0 %	30.8 %	100.0 %
Tuberculosis	40.0 %	59.7 %	30.7 %	46.5 %	50.4 %	61.5 %	80.6 %
Vitamins and Minerals		99.0 %	88.0 %	97.7 %	99.8 %	26.6 %	

Note: IMS data. Means over 2015-2017 for all countries except Philippines (2013-2016). Private sector only for Kerala and Senegal.

C.4 Additional Descriptive Statistics

Table 15: *Average price of molecules present in all countries*

			All					
molecule	Kerala	Philippines	Senegal	Serbia	South Africa	Tunisia	Zambia	Total
AMOXICILLIN—CLAVULANIC ACID	13.64	0.38	4.44	0.32	3.67	0.48	0.23	3.25
BISOPROLOL	4.23	0.50	4.61	0.06	2.73	0.09	0.07	1.46
CIPROFLOXACIN	3.27	0.22	3.28	0.26	0.80	0.18	1.50	1.05
DICLOFENAC	1.45	0.36	2.21	0.07	0.55	0.05	0.10	0.54
ENALAPRIL	4.84	0.26	4.41	0.06	1.96	0.16	0.81	1.48
METFORMIN	1.47	0.11	1.26	0.03	3.32	0.04	0.03	0.86
OMEPRAZOLE	2.24	2.34	4.65	0.23	4.49	0.42	0.04	1.78
SALBUTAMOL	0.43	0.12	2.91	0.03	1.28	0.01	0.01	0.48
SIMVASTATIN	8.37	0.39	7.66	0.06	1.02	0.18	0.15	2.05
Total	4.44	0.53	3.94	0.13	2.07	0.18	0.33	1.43
			Private					
molecule	Kerala	Philippines	Senegal	Serbia	South Africa	Tunisia	Zambia	Total
AMOXICILLIN—CLAVULANIC ACID	13.64	0.36	4.44	0.29	3.90	0.48	0.23	4.30
BISOPROLOL	4.23	0.50	4.61	0.07	3.62	0.19	0.07	1.87
CIPROFLOXACIN	3.27	0.25	3.28	0.25	1.61	0.25	1.50	1.48
DICLOFENAC	1.45	0.36	2.21	0.07	1.29	0.08	0.20	0.78
ENALAPRIL	4.84	0.28	4.41	0.06	2.73	0.29	2.40	2.08
METFORMIN	1.47	0.14	1.26	0.03	3.54	0.07		0.88
OMEPRAZOLE	2.24	2.60	4.65	0.17	9.51	0.66	0.05	2.28
SALBUTAMOL	0.43	0.11	2.91	0.02	1.79	0.01		0.57
SIMVASTATIN	8.37	0.43	7.66	0.07	2.15	0.34	0.20	3.04
Total	4.44	0.56	3.94	0.12	3.35	0.26	0.56	1.95
			Public decentralized					
molecule	Philippines	South Africa	Total					
AMOXICILLIN—CLAVULANIC ACID	0.41		0.41					
BISOPROLOL	0.52	1.84	1.18					
CIPROFLOXACIN	0.17		0.17					
DICLOFENAC	0.35		0.35					
ENALAPRIL	0.22		0.22					
METFORMIN	0.09		0.09					
OMEPRAZOLE	1.99		1.99					
SALBUTAMOL	0.14		0.14					
SIMVASTATIN	0.30		0.30					
Total	0.53	1.84	0.64					
			Public centralized					
molecule	Philippines	Serbia	South Africa	Tunisia	Zambia	Total		
AMOXICILLIN—CLAVULANIC ACID		0.37	3.44	0.47		1.16		
BISOPROLOL		0.04		0.00		0.03		
CIPROFLOXACIN	0.21	0.27	0.40	0.12		0.29		
DICLOFENAC		0.08	0.17	0.02	0.00	0.10		
ENALAPRIL		0.06	1.57	0.03	0.02	0.55		
METFORMIN	0.06	0.03	3.21	0.02	0.03	0.94		
OMEPRAZOLE		0.32	1.14	0.18	0.01	0.51		
SALBUTAMOL		0.03	1.03	0.01	0.01	0.36		
SIMVASTATIN		0.06	0.46	0.02	0.04	0.19		
Total	0.11	0.14	1.30	0.10	0.02	0.47		

Note: Price in US$ by Std Unit.

C.5 First Stage Results

Table 16: *Product-level effect of procurement on prices: restricted samples*

	(1)	(2)	(3)
	Public decentralized×HHI	Public centralized×HHI	Private×HHI
Generic available	-0.1679***	-0.1150	0.0080
	(0.0411)	(0.0614)	(0.0658)
Nb mol. purchased by Area	-0.0284	-0.0304	-0.0147
	(0.0184)	(0.0275)	(0.0295)
Public decentralized	-0.0256*	-0.0120	0.0150
	(0.0107)	(0.0160)	(0.0172)
Public centralized	-0.0178*	0.2786***	-0.2098***
	(0.0080)	(0.0120)	(0.0129)
Public decentralized*HHIother	-1.4305***	-4.9464***	-8.0559***
	(0.0811)	(0.1213)	(0.1300)
Public centralized*HHIother	-2.1371***	-4.5641***	-7.8619***
	(0.0800)	(0.1195)	(0.1281)
Private*HHIother	-2.1465***	-4.9738***	-7.3645***
	(0.0786)	(0.1175)	(0.1259)
N	6287	6287	6287
r2	.8238532	.9002252	.8995939
Country FE	Yes	Yes	Yes
Molecule×country×year FE	Yes	Yes	Yes
Method	OLS	OLS	OLS

*Note: ***, **, and * indicate significance at 1%, 5% and 10%, respectively.*

D Additional Robustness Checks

D.1 Subsamples

Table 17 presents the results from our key specification (columns (4) in Tables 8 and 10, for two specific subsamples. In columns (1) and (2), we restrict the sample to the nine common molecules that are sold by all the country included in the analysis. In columns (3) and (4), we focus on the three countries in which the public sector procures drugs through both centralized purchase mechanisms and decentralized purchases: the Philippines, Serbia, and South Africa. Columns (1) and (3) present our main specification, with molecule×country×year, as well as product fixed effects. Columns (2) and (4) add the selection control functions to this specification.

Table 17: *Product-level effect of procurement on prices: restricted samples*

	(1)	(2)	(3)	(4)
	Common molecules	Common molecules	3 countries	3 countries
Nb mol. purchased by Area	-0.2769*	-0.0443	0.3351	0.3152
	(0.1120)	(0.1144)	(0.2293)	(0.2299)
Public decentralized	0.0326	0.0222	-0.0139	-0.0347
	(0.0229)	(0.0300)	(0.0170)	(0.0233)
Public centralized	-0.3314***	-0.1381***	-0.1598***	-0.1400***
	(0.0281)	(0.0359)	(0.0226)	(0.0260)
N	4007	4007	4756	4756
r2	.9725259	.9732038	.9706736	.9707042
Country FE	Yes	Yes	Yes	Yes
Molecule×country×year FE	Yes	Yes	Yes	Yes
Product FE	Yes	Yes	Yes	Yes
Selection control	No	Yes	No	Yes
Method	OLS	OLS	OLS	OLS

*Note: In columns 1 and 2, the sample is restricted to the nine molecules common to all countries: AMOXICILLIN—CLAVULANIC ACID, BISOPROLOL, CIPROFLOXACIN, DICLOFENAC, ENALAPRIL, METFORMIN, OMEPRAZOLE, SALBUTAMOL, SIMVASTATIN. In columns 3 and 4, the sample is restricted to the three countries in which there is both public sector centralized and decentralized purchases mechanisms: the Philippines, Serbia, and South Africa. ***, **, and * indicate significance at 1%, 5% and 10%, respectively.*

D.2 Effects on Average Molecule Price

We study the effect of procurement systems on average price using the following regression model:

$$log(p_{icst}) = \alpha_{ic} + \gamma_{a(i)} + \lambda_s + \epsilon_{icst} \tag{4}$$

where i is the molecule, c the country, s the sector in the country (Private, Public centralized or Public decentralized) and t is the year.

The results in Table 18 are in line with the product-level ones discussed in Section 5. Centralized procurement allows the public sector to obtain prices that are between 41 and 58% lower (compare with 33% lower prices when using product-level data).

Table 18: *Regressions at Molecule Level*

	(1)	(2)	(3)	(4)
Generic available	-3.4492***	-1.3099***	-0.3024	-0.1199
	(0.1921)	(0.1782)	(0.3326)	(0.2203)
Public decentralized	0.5149*	-0.4662**	-0.2943*	-0.1621
	(0.2252)	(0.1743)	(0.1386)	(0.0953)
Public centralized	-0.4817**	-0.4135***	-0.5017***	-0.5824***
	(0.1500)	(0.1140)	(0.0888)	(0.0605)
Serbia	0.1884	-0.2746	-0.5480***	8.0941***
	(0.2067)	(0.1573)	(0.1291)	(0.4742)
South Africa	2.3908***	2.0839***	1.7731***	3.6111***
	(0.2309)	(0.1756)	(0.1367)	(0.5379)
Tunisia	0.0976	-0.1485	-0.2723	2.4119***
	(0.2488)	(0.1903)	(0.1539)	(0.5411)
Kerala	2.9966***	2.9796***	2.6495***	6.8293***
	(0.2333)	(0.1802)	(0.1407)	(0.4793)
Zambia	-0.5069	-0.6886**	-0.8262***	-0.7936
	(0.3047)	(0.2315)	(0.1792)	(0.7859)
Senegal	2.0655***	1.9355***	1.6723***	1.8022*
	(0.2945)	(0.2232)	(0.1721)	(0.7837)
N	1070	1070	1070	1070
Area fixed effects	No	Yes	Yes	Yes
Country fixed effects	Yes	Yes	Yes	Yes
Molecule fixed effects	No	No	Yes	Yes
Molecule×country fixed effects	No	No	No	Yes

*Note: ***, **, * indicate significance at 1%, 5% and 10% respectively.*