Pooled Procurement of Drugs in Low and Middle Income Countries*

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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 several years for forty important molecules. We find that centralized procurement of drugs by the public sector allows to obtain much 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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1 Introduction

Across Low and Middle Income Countries (LMICs), the prices of essential medicines such as cancer treatments, HIV antiretrovirals, or antibiotics display huge variations, with the locally observed prices being sometimes many times higher than the lowest international reference level. For example, among a group of nine common molecules that are 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 shows variations of up to 300 percent across procurement channels. High prices, in turn, deplete already limited public health budget 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 buyers' 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 Low and Middle Income Countries (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, going from single seller situations to very competitive environments.

We first develop a model where 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 way, an assumption well-suited to the context of low-and-middle-income countries, but become non-price-takers when centralizing procurement. Under fairly general assumptions, we show that in a duopoly

[1] See Section 4 for details.

setting, prices under centralized procurement are lower than prices under decentralized procurement. This result also extends to an oligopoly setting with an arbitrary number of firms.

We then use data from seven LMICs with diverse drug procurement systems in order to evaluate empirically which procurement mechanisms allow countries to access drugs at cheaper prices. More specifically, we use data from IMS Health (IQVIA), which covers exhaustively the sales quantities and expenditures of drugs for forty molecules at a finely disaggregated level by year and sector of purchase, over the period 2015-2017. The countries included in the analysis are India (the State of Kerala), The Philippines, Senegal, Serbia, South Africa (a subset of three States: KwaZulu-Natal, North West and Eastern Cape), Tunisia, and Zambia.

Consistently with the model's predictions, our main finding is that centralized procurement of drugs allows the public sector to obtain much cheaper prices. However, we also find that the price reduction is smaller when the supply side is more concentrated. At the extreme, the price difference vanishes when public buyers face a monopolistic supplier. These results come from exploiting variation across molecules and products, within-country-year and within therapeutic areas-year groups of observation. Indeed, 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 being bought in a decentralized way. Finally, we show that the price difference in favor of public centralized mechanisms does not arise from a higher demand elasticity in the public sector.

The economic literature dealing with 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 implied pricing policies, the main one being the exclusion of a large number of poor and uninsured patients, and the potential benefits related to the increased and faster diffusion of drugs to previously excluded markets (Cockburn et al. (2016)).

Those contributions, however, have not addressed other important potential sources of frictions in local drug markets, such as suppliers' market power and buyers' size, and the type of procurement mechanisms used by public buyers. These frictions are likely to matter especially for the large set of off-patent drugs. For molecules for which generics are available, market structure and purchasing mechanisms are likely to be paramount in determining local prices.

One mechanism that has been used to try to reduce unit purchase prices is pooled procurement, whereby several buyers, either institutions in a single country or health agencies across countries, consolidate their purchases.[2]

The existing theoretical literature on the impact of pooled procurement on prices shows that, in theory, 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 brings about higher prices if cost is concave.[3] Jeon and Menicucci (2017) also find that the shape of suppliers' cost functions matters for the impact of pooled procurement on prices in a model that extends the common agency setup (Bernheim and Whinston, 1986) to multiple suppliers. 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 can be either positive or negative depending on which equilibrium is selected.[4]

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

[2]Pooled procurement channels may vary, and include in particular the joint acquisition of large quantities at a given time, or the negotiation of contracts allowing for the supply of drugs over long periods.

[3]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 greater (less) than the former, which is the case when the supplier's cost is convex, then a buyer group allows to negotiate over a greater contribution.

[4]More specifically, they find a negative (positive) effect on prices when the Pareto-dominant equilibrium in terms of suppliers' (buyers') payoffs is selected.

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 generates both positive and negative effects on prices and leads to an ambiguous prediction regarding the net impact of a buyer group on prices.

In practice, pooled drug procurement mechanisms have been implemented among others 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), or the Pan American Health Organization (PAHO) Strategic Fund that groups seventeen countries for the purchase of vaccines. Similar arrangements have also been used to procure antiretroviral (ARV) drugs, through the United States President's Emergency Plan for AIDS Relief (PEPFAR) or the Global Fund to Fight AIDS, Tuberculosis, and Malaria (Global Fund) (see for example WHO (2007), and 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 for example 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 volumes for twelve ARVs using the same data. Seidman and Atun (2017) offer 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.

More recently, 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 may vary depending on the composition of the pool of buyers. In particular, they conclude that adding buyers with higher credit risk may drive up the price paid by the buyer group.

None of these studies, however, relies on large cross-country, cross-pharmaceutical class drug price data, and addresses potential confounding factors related to the market structure of suppliers, an issue that seems key for drug procurement in LMICs, given the large potential market power accruing to big pharma firms in certain regions or types of drugs.

The paper is organized as follows. Section 2 describes the procurement institutions in our sample countries. Section 3 presents the 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. Proofs of theoretical results, additional descriptive statistics and robustness checks are relegated to the Appendix.

2 Procurement Systems

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

As can be seen from the table, these countries' health sectors constitute a sample with relatively diverse characteristics. In terms of level of development, it goes from low income (Senegal and Zambia) to upper middle income countries (Serbia and South Africa), and covers both small and large countries population-wise. Accordingly, there is huge variation, by a factor of 15, in terms of the size of the health commodity market.

In terms of the structure of spending, and the role of the public vs. the 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 spending from private sources, and out-of-pocket. Finally, at least one of the countries in the sample, Zambia, relies quite heavily on external aid (for about 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 both through centralized purchase mechanisms and through 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 ones are procured centrally by country. Importantly, all three countries present within-therapeutic area variation in terms of the coverage of centralized procedures, so for example for each of these countries our sample of molecules includes both 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 way by specific health institutions.

Table 1: *Countries 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 = 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 the data on public purchases is available.

Table 2: *Molecules procured centrally by country*

Therapeutic area	Molecule	South Africa	Philippines	Serbia
Anaemia	ERYTHROPOIETIN ALPHA	1	0	0
Anti-Ulcerants	OMEPRAZOLE	1	0	1
Anti-hypertensives	BISOPROLOL	0	0	1
Anti-hypertensives	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 Anti-retrovirals	TENOFOVIR DISOPROXIL	1	1	1
HIV Anti-retrovirals	EFAVIRENZ	1	1	1
HIV Anti-retrovirals	LAMIVUDINE	1	1	1
HIV Anti-retrovirals	SOFOSBUVIR	0	0	0
HIV Anti-retrovirals	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.

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, of course, remain so if they engage in pooled procurement. In 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 (that has received much attention in the literature), it is natural to assume that the buyers are non-price takers even in the absence of a buyer group. However, in our setting, i.e., drug procurement in Low and Middle Income Countries, it seems reasonable to assume that buyers (e.g., pharmacies and hospitals) are price-takers if the system is fully decentralized.

We first derive the effect of centralized procurement on prices in a simple duopoly setting and then show that our findings hold in a more general oligopoly setting.

3.1 Basic Setup

Consider two firms competing against each other and producing two differentiated products, 1 and 2, at marginal costs c_1 and c_2 respectively. Denote $D_1(p_1, p_2)$ and $D_2(p_1, p_2)$ the demands for products 1 and 2, respectively, when their prices are given by p_1 and p_2. We assume that each firm i's profit function is strictly concave in its own price and that its best-response function $R_i(.)$ is increasing in its rival's price (i.e., prices are strategic complements). We suppose further that a Nash equilibrium (p_1^*, p_2^*) to the Bertrand game exists and is unique.

Procurement of the two products can be decentralized or centralized. We suppose that the Bertrand-Nash prices prevail under the decentralized regime. This implies in particular that buyers are price takers in this scenario. In contrast, under centralized procurement, we suppose that a single entity, say a governmental agency, negotiates prices by engaging in simultaneous Nash bargaining with both firms. We assume that the governmental agency's objective function takes the general form $W(p_1, p_2)$ where $W(.,.)$ is differentiable and decreasing over $[c_1, +\infty) \times [c_2, +\infty)$. For instance, $W(p_1, p_2)$ could be consumer surplus, social welfare or coverage. Thus, the prices that arise under centralized procurement solve the following system of maximization programs:

$$\max_{p_1 \geq c_1} \left[(p_1 - c_1) D_1(p_1, p_2)\right]^{1-\alpha_1} \left[W(p_1, p_2) - W(\infty, p_2)\right]^{\alpha_1} \tag{1}$$

$$\max_{p_2 \geq c_2} \left[(p_2 - c_2) D_2(p_1, p_2)\right]^{1-\alpha_2} \left[W(p_1, p_2) - W(p_1, \infty)\right]^{\alpha_2} \tag{2}$$

where $\alpha_1 \in (0, 1]$ and $\alpha_2 \in (0, 1]$ capture the bargaining power of the governmental agency in its negotiation with firms 1 and 2 respectively. Note that the limiting case $\alpha_1 = \alpha_2 = 0$ corresponds to the Bertrand-Nash equilibrium (i.e. the equilibrium that would prevail under decentralized procurement). We assume that the solution to (1) (resp. (2)), which we denote $\tilde{R}_1(p_2)$ (resp. $\tilde{R}_2(p_1)$) is unique for any p_2 (resp. p_1) and characterized by the corresponding first-order-condition. Moreover, we assume that the pair $(\tilde{p}_1, \tilde{p}_2)$ solving the system exists and is unique.

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

Proposition 1. *In our duopoly setting, 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 two firms 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 price of the other product. We show, however, that in a fairly general setting, the equilibrium prices do decrease when one switches from a decentralized to a centralized procurement regime.

Further, it is easy to see that Proposition 1 would still hold if marginal costs were strictly increasing or strictly decreasing. This stands in sharp contrast to the existing papers on buyer groups emphasizing the curvature of the cost function as a key determinant of the profitability of a buyer group.

3.2 Generalization

We now consider a more general scenario in which $N \geq 2$ firms compete in prices. We denote c_i the marginal cost of firm i and assume again that the products sold by the firms are differentiated. Denote $\boldsymbol{p} = (p_1, p_2, ..., p_N)$ the vector consisting of all the prices set by the N firms, $\boldsymbol{p}_{-i}$ the vector derived from $\boldsymbol{p}$ by removing firm i's price p_i, and $D_i(\boldsymbol{p})$ the demand addressed to firm 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.

The prices that prevail under (fully) decentralized procurement are the Bertrand-Nash prices $\boldsymbol{p}^* = (p_1^*, p_2^*, ..., p_N^*)$, while the prices under centralized procurement, which we assume to exist and be unique, solve the following maximization programs:

$$\max_{p_i \geq c_i} \left[(p_i - c_i) D_i(p_i, \boldsymbol{p}_{-i})\right]^{1-\alpha_i} \left[W(p_i, \boldsymbol{p}_{-i}) - W(\infty, \boldsymbol{p}_{-i})\right]^{\alpha_1} \tag{3}$$

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, and $W(.)$ is its objective function. We assume that the latter is differentiable and decreasing over $[c_1, +\infty) \times [c_2, +\infty) \times ... \times [c_N, +\infty)$ and that the solution to (3) for a given $\boldsymbol{p}_{-i}$, which we denote $R_i(\boldsymbol{p}_{-i})$ is unique 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 N 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 (3) for each $i = 1, 2, ..., K$.

We are now able to compare prices under decentralized procurement to those under centralized procurement. The next result shows that Proposition 1 generalizes to a setting with any number $N \geq 2$ of firms.

Proposition 2. *In our oligopoly setting with an arbitrary number of firms N, prices under centralized procurement are lower than prices under decentralized procurement.*

Proof. See Appendix. □

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 a 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.[5]

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 unchanged the set of available goods is to fix the number of goods and allow some firms to produce more than a single good (e.g. to produce at the same time a branded drug and a generic drug).[6] Under our assumptions, one can readily check that increasing the number of products sold by a given firm (or, equivalently, merging two or more firms) leads to higher prices under

[5]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.

[6]Performing comparative statics with respect to N would be misleading in our setting as this would affect at the same time supply-side concentration and product variety. In an alternative setting with N homogeneous goods produced by (single-product) firms competing in quantities, varying N would be a sound way of examining the impact of supply-side concentration.

both centralized and decentralized procurement. This implies that the theoretical impact of supply-side concentration on the differences between prices in the two procurement regimes is generally ambiguous, which suggests that this question should be approached empirically, as we will 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 Low and Middle Income Countries with diverse drug procurement systems: four middle income countries –the Philippines, three States in South Africa (KwaZulu-Natal, North West and Eastern 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 Serbia 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 happen in a centralized or decentralized way.

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 to be related to the different needs of the respective populations, to patent and regulatory policies, as well as to supply-side factors such as producers' marketing strategy.

Table 4 reports descriptive statistics by country and sector/channel of procurement. It lists the number of molecules purchased and their mean prices. It also shows the mean prices of the nine molecules that are purchased in all the countries for which we have data, which are 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.[7]

The comparison of mean prices shows a lot of heterogeneity across countries as well as within country 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 pay 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 the public sector. Also, surprisingly, low income countries do not necessarily pay lower prices, as Senegal and Kerala pay much more than Tunisia and Serbia. Our first aim is to estimate how much of these differences can be ascribed to different procurement procedures, once we account for country- and therapeutic area-level specific effects.

[7]A standard Unit (SU) is a standard IMS derived measure of the number of doses. It is measured differently depending on the formulation of the medicine, with one SU usually being equal to one tablet, one capsule, one suppository, one pre-filled syringe/cartridges, pen, vial or ampoule, one dose of an inhaled medicine or 5ml of a oral syrup or suspension. 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	SouthAfrica	Tunisia	Zambia
Anaemia	ERYTHROPOIETIN ALPHA		X	X	X			
Anti-Ulcerants	OMEPRAZOLE	X	X	X	X	X	X	X
Anti-hypertensives	BISOPROLOL	X	X	X	X	X	X	X
Anti-hypertensives	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 Anti-retrovirals	TENOFOVIR—LAMIVUDINE—EFAVIRENZ	X				X		X
HIV Anti-retrovirals	EFAVIRENZ						X	
HIV Anti-retrovirals	LAMIVUDINE						X	
HIV Anti-retrovirals	SOFOSBUVIR	X					X	
HIV Anti-retrovirals	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 areas.

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	
SouthAfrica	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

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, 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.[8] Within the selected ATC3 categories, there is large variation in terms of the share accounted for by the selected molecules, from South Africa that has relatively low coverage, to Tunisia and Zambia, where most of public expenses are included.

[8]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 correspond 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
SouthAfrica	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 the one of the 40 molecules studied. Exhaustive ATC3 level data on Senegal are missing.

For a given molecule, when generics are available it is possible to purchase different brands (different products) from different manufacturers. Table 6 shows the number of molecules purchased, as well as the corresponding number of products and manufacturers. It further breaks this down by procurement sector and channel. This shows that the public sector usually purchases fewer molecules, fewer products, and from fewer manufacturers.

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
SouthAfrica	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

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

Table 7: *Therapeutic area expenditure shares by country*

Area Country	Kerala	Philippines	Senegal	Serbia	SouthAfrica	Tunisia	Zambia
Anaemia		5.79 %		1.17 %			
Anti-Ulcerants	7.18 %	8.31 %	27.14 %	1.38 %	19.94 %	6.77 %	.01 %
Anti-hypertensives	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 Anti-retrovirals	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 Philippines (2013-2016). Private sector only for Kerala and Senegal.

Tables 7 to 9 provide additional descriptive statistics for the selected therapeutics areas and molecules included in our analysis. Table 7 details the distribution of country-level expenditures, showing that our sample provides relatively exhaustive coverage of therapeutic areas for the countries in the sample.[9] Table 8 shows the mean HHI concentration index of manufacturers by therapeutic areas, computed as the sum of squared market shares (in quantities) of each manufacturer within the country, sector, year and therapeutic area. It shows that there is large variations in concentration, but also that many country-therapeutic areas display high providers' concentration. A similar table using the C1 concentration index is provided in the Appendix. Finally, table 9 shows the sample relative shares of public and private purchases by country.

[9]Table 12 in the Appendix provides a benchmark consisting of the same information for all molecules in these categories.

Table 8: *Concentration by therapeutic area for each country (HHI)*

Area / Country	Kerala	Philippines	Senegal	Serbia	SouthAfrica	Tunisia	Zambia
Anaemia		54.7 %	100.0 %	82.4 %			
Anti-Ulcerants	28.8 %	32.8 %	12.0 %	63.0 %	50.9 %	36.6 %	77.9 %
Anti-hypertensives	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 Anti-retrovirals	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 shares (in quantities) of each manufacturer by country, year, and therapeutic area for the sample molecules. Means over 2015-2017 for all countries except Philippines (2013-2016). Private sector only for Kerala and Senegal.

Table 9: *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 %

Note: IMS data. Share of total sample expenditures by sector and channel. Means over 2015-2017 for all countries except 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 estimation at the level of products (standard units). In Appendix D, we also include the results from running estimations at the level of molecules. While this higher level of aggregation reduces the sample from over six thousands observations to around one thousand, the results remain basically unchanged.

5.1 Effects on Average Product Price

We estimate the following regression model:

$$log(p_{jcst}) = \alpha_{jc} + \gamma_{a(j)t} + \lambda_s + \epsilon_{jcst} \tag{4}$$

where j is the product, c the country, s the sector in the country (private, public centralized or public decentralized) and t is the year. The parameter α_{jc} is a product*country specific effect that will sometimes be restricted to be additively separable as follows: $\alpha_{jc} = \alpha_j + \alpha_c$. The parameter $\gamma_{a(j)t}$ is an area*year specific effect (where $a(j)$ denotes the therapeutic area of product j) that will sometimes be restricted to be additively separable as follows: $\gamma_{a(j)t} = \gamma_{a(j)} + \gamma_t$.

Columns (1) to (3) of Table 10 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 product*country and area*year fixed effects. It is also important to note that the results are driven not only by cross-country, cross-procurement mechanisms variation, but also by the within-therapeutic areas, cross-molecules variation depicted in Table 2.

We then interact the procurement channel variables with the Herfindahl-Hirschman Index (HHI) of the suppliers in each therapeutic area, country and year. Column (4) shows the results obtained by OLS. There is, however, an obvious problem of endogeneity of HHI indexes within this price equation. Since prices affect demands and market shares, it is likely that unobserved factors at the country-therapeutic area-year level affect both demands and prices and thus generate some unobserved correlations with both prices and market shares. In column (5), we thus use a Two Stages Least Squares estimation where we instrument for these interactions.

We use HHI indexes of the same therapeutic area 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 that have common determinants across countries since most manufacturing firms are international and operate in many countries. However, the demand side factors that explain the variations across countries of HHI indexes are likely to be uncorrelated.

When using this IV estimation technique, we find that the price reduction obtained by the public sector using a centralized procurement system is negative and significant, and that it is lower when the HHI index is higher, converging to zero when the HHI index reaches 94%. In our sample, country-therapeutic areas HHI values at or above 94% are actually not exceptional. This shows that the supply side market power of firms matters, and that it may hamper the ability of the public sector centralized procurement mechanism to induce lower prices.

Table 10: *Product level effect of procurement and market power on prices*

	(1)	(2)	(3)	(4)	(5)
Generic available	-0.2853	-0.1578	-0.2996	-0.3044	-0.2962
	(0.1947)	(0.1637)	(0.2978)	(0.2973)	(0.3016)
Nb mol. purchased by Area	-0.2454***	-0.0089	-0.0899	-0.0906	-0.0489
	(0.0362)	(0.1375)	(0.1557)	(0.1556)	(0.1582)
Public decentralized	-0.0692	-0.0492	-0.0474	0.0946	-0.0766
	(0.0548)	(0.0460)	(0.0461)	(0.0841)	(0.1841)
Public centralized	-0.3998***	-0.4356***	-0.4365***	-0.1299	-1.1874***
	(0.0471)	(0.0409)	(0.0410)	(0.0914)	(0.2748)
Public decentralized*HHI				0.0265	-0.1704
				(0.2122)	(0.5261)
Public centralized*HHI				-0.2302	1.2602**
				(0.1492)	(0.4218)
Private*HHI				0.4671***	-0.2676
				(0.1178)	(0.2137)
N	6126	6126	6126	6126	6126
Area fixed effects	Yes	Yes	Yes	Yes	Yes
Area*year fixed effects	No	No	Yes	Yes	Yes
Molecule fixed effects	Yes	Yes	Yes	Yes	Yes
Country fixed effects	Yes	Yes	Yes	Yes	Yes
Molecule*country fixed effects	No	Yes	Yes	Yes	Yes
Method	OLS	OLS	OLS	OLS	2SLS

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

The above results show the potential price reduction obtained by the public sector using a centralized procurement system for different levels of suppliers' concentration measured through the HHI index. The regression results show clearly that centralized procurement commands lower prices as long as the supplier HHI index is low. On the other hand, one can compute the combined effect confidence intervals that shows that the price difference across channels ceases to be significantly different for HHI values of around 0.6. In addition, note that neither private nor decentralized public procurement are affected much by HHI.

We have argued that the public centralized procurement channel allows for lower prices, which in turn leads to greater quantities being purchased. We have also shown that this effect is stronger, the lower the supplier concentration index. Starting from actual HHI levels observed in the data, we can perform a reduced form estimation of the impact of an increase in competition among suppliers on the potential increase in the quantity procured, keeping budget constant.

We do this by regressing the log of product quantities on the interaction between HHI and procurement channels, at the country, therapeutic area, year level. When instrumenting for HHI in the same way as in Table 10, we find a coefficient of -8.2, significant at the 1% level for centralized procurement. This means that a reduction in suppliers' concentration from the median HHI value of 0.28 to the 25th percentile value 0.17 would increase the quantity purchased through public centralized procurement by 82%. In countries where the amount of drugs purchased publicly fails to satisfy internal demand, this suggests large potential gains in coverage from increasing market competition.

5.2 Reduced Form Demand

The previous empirical evidence is not a complete proof of a causal relationship between procurement mechanisms and prices. Although the results rely on within country-therapeutic area variation across molecules in each period, the short time span of the sample does not allow us to observe variations in the procurement mechanisms used within a country-therapeutic area over time that could be interpreted as a natural experiment. In the absence of such exogenous variations, we can however test for potential confounding factors.

In particular, we test whether the price differences across these mechanisms could be coming 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 do so we estimate reduced-form elasticity relationships using our quantity and expenditure data. More specifically, we use the following reduced form demand equation:

$$\log(y_{jcst}) = \alpha_{jc} + \gamma_{a(j)t} + \lambda_s + \beta_s \log(p_{jcst}) + \epsilon_{jcst} \tag{5}$$

where y_{jcst} is the aggregate demand of product j in country c, sector s and year t, and the parameters α_{jc} and $\gamma_{a(j)t}$ are defined as above. The parameter β_s is the reduced form price elasticity of demand. It will be first constrained to be identical across sectors and then allowed to vary.

This demand equation is likely to suffer from price endogeneity. In columns (4) and (6) of Table 11 we therefore implement 2SLS estimates using the mean prices of the same products in the same procurement channel of all other countries as instrumental variables.

Table 11, columns (1) to (3), shows an average price elasticity of between -0.72 and -0.75, when we do not instrument prices, which is quite stable across different fixed effects combinations. When we instrument for price (column (4)), this average elasticity increases in magnitude to -0.94. When we allow the elasticity to differ across procurement mechanisms (column (5)), and instrument for prices as indicated above (column (6)), we find a price elasticity of around -1 for the private sector and the decentralized procurement public sector while it is slightly lower, around -0.8, for the centralized public sector.

This supports 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 the centralized public procurement.

Table 11: *Reduced form demand at product level*

	(1)	(2)	(3)	(4)	(5)	(6)
log(price product)	-0.7539***	-0.7192***	-0.7183***	-0.9433***		
	(0.0348)	(0.0419)	(0.0421)	(0.2478)		
log price * Private					-0.6467***	-1.0489***
					(0.0444)	(0.2596)
log price * Public decentralized					-0.3595***	-0.9819***
					(0.0723)	(0.2690)
log price * Public centralized					-1.1919***	-0.7878**
					(0.0630)	(0.2759)
Generic available	-0.2029	0.1635	-0.1865	-0.0955	-0.3363	-0.0289
	(0.5295)	(0.5296)	(0.9645)	(0.9515)	(0.9560)	(0.9604)
Public decentralized	-1.0944***	-1.0443***	-1.0461***	-0.9716***	-0.7728***	-0.9157***
	(0.1491)	(0.1490)	(0.1493)	(0.1509)	(0.1607)	(0.1931)
Public centralized	0.1059	-0.0404	-0.0406	-0.1523	-0.7326***	0.1539
	(0.1288)	(0.1338)	(0.1341)	(0.1698)	(0.1514)	(0.2569)
N	6123	6123	6123	5886	6123	5886
Area fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Area*year fixed effects	No	No	Yes	Yes	Yes	Yes
Molecule fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Country fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Molecule*country fixed effects	No	Yes	Yes	Yes	Yes	Yes
Method	OLS	OLS	OLS	2SLS	OLS	2SLS

*Note: 2SLS refers to the Two Stages Least Squares Prices in other markets are used as instrumental variables for prices. ***, **, * indicate significance at 1%, 5% and 10% respectively.*

6 Conclusion

We analyze the impact of pooled procurement on drug purchase prices and study the way this effect depends on drug markets demand- and supply-side concentration in seven Low and Middle Income Countries (LMICs), using cross-country, cross-procurement channel, and also within-therapeutic areas, cross-molecules variation in how public buyers procure drugs. Consistently with the predictions of a simple theoretical model, our empirical results show that centralized procurement systems allow public buyers to obtain significantly lower prices.

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 lower prices in centralized public procurement are unlikely to be explained by a higher demand elasticity. If anything, this elasticity appears to be lower in the public centralized 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 order. These two channels are of course hard to disentangle, as they happen simultaneously. Further research would be needed to identify the nature of market interactions between buyers and sellers and separate their effect from those of transaction size.

Finally, our results have important policy implications. Indeed, simple reduced estimations of the impact of introducing additional supply side competition show large potential increases in the quantity of drugs that public sectors could purchase for a given level of their budget. In future research, we hope to be able to confirm these insights for a larger sample of countries and periods, as well as using cases of variations in the procurement mechanisms used within a country-therapeutic area over time.

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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 (Republic of Zambia, 2008). The ZPPA handles all government expenditures above 500,000 ZMW or USD $100 000 (Engstrand, 2013). 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.

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) (Limited, 2012). 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.

B Proofs of Section 3

Proof of Proposition 1

Let us first consider 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

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

and

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

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

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

and

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

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:

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

Moreover, it must hold that

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

for $p_1<p_1^*$, and

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

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

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

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

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

for any p_1, and in particular

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

which leads to a contradiction.

Therefore, $\tilde{p}_1 < p_1^*$. Likewise, $\tilde{p}_2 < p_2^*$.

Proof of Proposition 2

We proceed by induction. Proposition 1 shows that the result is true for the case $N = 2$. We now show that the result holds for a given $N \geq 3$ whenever it holds for $N - 1$, which will prove the result.

Let us assume that the result holds for an oligopoly with a number $N-1$ of 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 $\hat{D}_i(p_1, p_2, ..., p_{N-1}) = D_i(p_1, p_2, ..., p_N)$, and an objective function $\hat{W}$ defined by $\hat{W}(p_1, p_2, ..., p_{N-1}) = W(p_1, p_2, ..., p_N)$. Therefore, denoting $\left(R_1^*(p_N), R_2^*(p_N), ..., R_{N-1}^*(p_N)\right)$the Nash equilibrium of the Bertrand game and where p_N is fixed, and $\left(\tilde{R}_1^*(p_N), \tilde{R}_2^*(p_N), ..., \tilde{R}_{N-1}^*(p_N)\right)$ the prices under centralized procurement when p_N is fixed, we have that

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

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 $\tilde{R}_i^*(\tilde{p}_N) < R_i^*(\tilde{p}_N)$ yields

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

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

C Additional Tables

C.1 Therapeutic Area Expenditure Shares

Table 12: *Therapeutic Area Expenditure Shares by Country*

Area / Country	Kerala	Philippines	Serbia	SouthAfrica	Tunisia	Zambia
Anaemia	2.51 %	3.93 %	1.70 %	1.25 %	1.61 %	.29 %
Anti-Ulcerants	7.40 %	3.14 %	3.44 %	4.53 %	5.05 %	.13 %
Anti-hypertensives	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 Anti-retrovirals	.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.2 Concentration Index (C1)

Table 13: *Concentration by Area for each Country (C1)*

Area Country	Kerala	Philippines	Senegal	Serbia	SouthAfrica	Tunisia	Zambia
Anaemia		66.4 %	100.0 %	88.1 %			
Anti-Ulcerants	44.4 %	44.0 %	18.4 %	72.1 %	61.4 %	50.4 %	81.3 %
Anti-hypertensives	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 Anti-retrovirals	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.3 Additional Descriptive Statistics

Table 14: *Average price of molecules present in all countries*

molecule	All Kerala	Philippines	Senegal	Serbia	SouthAfrica	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

molecule	Private Kerala	Philippines	Senegal	Serbia	SouthAfrica	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

molecule	Public decentralized Philippines	SouthAfrica	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

molecule	Public centralized Philippines	Serbia	SouthAfrica	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.

D Effects on Average Molecule Price

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

$$log(p_{icst}) = \alpha_{ic} + \gamma_{a(i)} + \lambda_s + \epsilon_{icst} \tag{6}$$

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 15 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 40 and 44% lower prices when using product-level data).

Table 15: *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)
SouthAfrica	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.*

Are the differences in prices across sectors due to the differences of the demand shape of those sectors? As shown in table 16, the demand elasticity computed at the molecule level again appears to be lower for the centralized procurement channel.

$$\log(y_{icst}) = \alpha_{ic} + \gamma_a(i) + \lambda_s + \beta \log(p_{icst}) + \epsilon_{icst} \tag{7}$$

where y_{icst} is the aggregate demand of molecule i in country c, sector s and year t.

Table 16: *Reduced Form Demand at molecule level*

	(1)	(2)	(3)	(4)	(5)
log(price molecule)	-0.8692***	-0.8869***			
	(0.0620)	(0.0792)			
log price * Private			-0.8250***	-0.6561***	-2.2836**
			(0.0889)	(0.1307)	(0.7777)
log price * Public decentralized			-0.9108***	-0.7729***	-3.0830***
			(0.1675)	(0.1962)	(0.9116)
log price * Public centralized			-0.9479***	-1.0581***	-1.3681*
			(0.0892)	(0.1285)	(0.5862)
Generic available	-0.4212	-0.0622	-0.0546	0.0795	-0.0955
	(0.3661)	(0.8426)	(0.8426)	(0.8043)	(0.8551)
Public decentralized	-1.0246**	-0.9188**	-0.9126**	-0.7993*	-1.0045*
	(0.3503)	(0.3518)	(0.3530)	(0.3492)	(0.3985)
Public centralized	-0.0883	-0.0660	-0.1318	-0.5309*	-0.1057
	(0.2298)	(0.2283)	(0.2322)	(0.2411)	(0.4670)
N	1070	1070	1070	1070	1070
Area fixed effects	Yes	Yes	Yes	Yes	Yes
Country fixed effects	Yes	Yes	Yes	Yes	Yes
Molecule fixed effects	No	Yes	Yes	Yes	Yes
Molecule*country fixed effects	No	No	No	Yes	Yes
Method	OLS	OLS	OLS	OLS	2SLS

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