# Model Appendix:
# Spatial Differentiation Two Sector Model of Antimicrobial Resistance in LMIC

Consider a spatial differentiation model with two sectors selling pharmaceuticals, government G serving $N$ consumers and private V serving the remaining consumers, $1-N$ (where the total market is normalized to 1). We assume that total antimicrobial resistance, denoted by $R$, is a function of total consumption of antimicrobials, as well as the resistance rate per unit of consumption, which may differ between the public and private sectors:

$$R = r_G N Q_G + r_V (1-N) Q_V$$

Because in low-income countries the private sector is typically unregulated, or at least less regulated compared to the public sector, we assume that the antimicrobial resistance per unit of consumption in the private sector is higher than in the public sector: $r_V > r_G$. This greater resistance generation per pill consumed in the private sector can arise for multiple reasons: (a) there is a greater likelihood of counterfeit medication or pills of lower quality; (b) patients are more likely to complete only a truncated course of treatment, partly because they can pay by the pill (so that out-of-pocket payment is actually less than the market price for a full course of treatment P, and may in fact be less than the out-of-pocket price in the public sector); and (c) antibiotics are more likely to be consumed even by patients for whom they are inappropriate (e.g. viral infections). Thus, total resistance increases if (1) total consumption increases, holding the sector mix constant; or (2) private sector consumption increases relative to public sector consumption, holding total consumption fixed.

We show that increasing the co-payment requirement in the public sector is associated with increased total resistance under a fairly straightforward set of assumptions. First, consider the simplest case of unit demand: each patient consumes a unit quantity $Q=1$, but substitutes between the public and private sectors. The market price for the full course of treatment, P, is the same in the two sectors. However, treatment in the public sector may be differentially subsidized or covered by insurance so that the co-payment is less than the full market price. Let $\theta \leq 1$ denote the co-payment requirement in the public sector, where $\theta P$ represents the patient's out-of-pocket spending on the pharmaceutical in the public sector. Thus fraction $(1-\theta)$ of the price is covered by government subsidy and/or insurance.

Private sector providers, such as pharmacies, are ubiquitous and unregulated in LMICs. Ubiquity implies there is little travel or transaction cost associated with purchasing a pill at a pharmacy (normalized to zero). By contrast, government clinics require some transaction cost $T_i$ because of travel and wait time, the opportunity cost of which may differ for each patient $i$. The total price a patient pays at the public sector is thus $\theta P + T_i$, compared to the private sector price of P. Therefore, if the perceived product quality is the same and monetary price the same ($\theta = 1$), patients would prefer the conveniently ubiquitous private providers ($P < P + T_i$ for any $T_i > 0$). Specifically, each individual $i$ will go to the public sector if and only if their total price -- out-of-pocket spending for the drug and the differential travel and wait time costs -- is lower in the public sector than the private sector: $\theta P + T_i < P$. Assuming a simple uniform

distribution of $T_i$ along a unit line, the market share of consumers who will visit the public sector is given by the transaction cost that makes the marginal patient indifferent: $T_G = N = P(1-\theta)$ . More patients substitute from the private to the public sector as $(1-\theta)$ (the share of the price covered by subsidy or insurance) increases, i.e., as public sector co-payments $\theta$ decrease.

In this simple horizontal differentiation model, the total consumption of antimicrobials is constant ( $Q$ ), and the co-payment change merely shifts demand between the public sector ( $NQ$ ) and the private sector ( $(1-N)Q$ ). Total antimicrobial resistance is increasing in the public sector co-payment: $\frac{dR}{d\theta} = -\frac{dN}{d\theta}(r_V - r_G) = -(-P)(r_V - r_G) > 0$ because $r_V > r_G$.

A slightly more nuanced model that allows for downward-sloping demand in each sector will also yield an increase in total resistance when $\theta$ increases as long as the substitution of patients from public to private sector, and the greater resistance per unit consumption in the private sector, outweighs the direct reduction in consumption in the public sector from the higher co-payment.

We hypothesize that as a country develops, the differential in out-of-pocket spending and in resistance per unit prescription between the public and private sectors will likely decrease, as improved regulation and enforcement of prescriptions reduces inappropriate self-medication at pharmacies, and private providers also treat insured patients. The model suggests that total resistance will then depend less on the distribution of patients between the two sectors, and more on the overall level of appropriate prescribing ( $r_V \approx r_G$ ) and total consumption ( $Q$ ).