Appendix A

The introduction of a T&T system does not necessarily coincide with a change in cigarette prices, but the model allows for such price changes. The step-by-step mechanics of the model are as follows:

1) For each market segment X, the price increases from $p_{X(T-1)}$ to $p_{X(T)}$, where T is the period after T&T is implemented, and $T-1$ is the period before T&T is implemented. The absolute difference between $p_{X(T-1)}$ and $p_{X(T)}$ will depend on ρ (the extent to which the illicit price increases relative to the cheapest legal segment price), and α (the percentage increase in the legal net-of-tax price).

2) For each market segment X, consumption responds to the price change in two ways:
   i. A within-segment demand reduction as $p_{X(T)}$ increases (consumers quit or reduce daily demand). This change in consumption is dependent on the own-price elasticity of demand ε_X and is calculated as follows:

$$C\_Prelim_{X(T)} = C_{X(T-1)} \times \frac{\left(1 + \varepsilon_X * {(p_{X(T)} - p_{X(T-1)})}\big/{(p_{X(T)} + p_{X(T-1)})}\right)}{\left(1 - \varepsilon_X * {(p_{X(T)} - p_{X(T-1)})}\big/{(p_{X(T)} + p_{X(T-1)})}\right)}$$

Equation 1

Where $C\_Prelim_{X(T)}$ is the preliminary consumption in segment X in time T (post-T&T) and $C_{X(T-1)}$ is consumption in segment X in $T-1$ (pre-T&T). This formula takes cognisance of the price change in segment X, but cross-segment substitution has not yet been accounted for. Equation 1 is derived from the standard formula for the arc elasticity of demand.

ii. As prices increase, some consumers shift to the next cheapest segment to maintain their consumption and to avoid the higher price. Consider a hypothetical market with two legal segments (premium a and discount b) and an illicit market, i. The consumption change is calculated as:

$$C\_Gain_{b(T)} = C\_Prelim_{b(T)} \text{ x } \left(\frac{\left(1 + \varepsilon_{ab} * \left(p_{a(T)} - p_{a(T-1)}\right) \Big/ \left(p_{a(T)} + p_{a(T-1)}\right)\right)}{\left(1 - \varepsilon_{ab} * \left(p_{a(T)} - p_{a(T-1)}\right) \Big/ \left(p_{a(T)} + p_{a(T-1)}\right)\right)} - 1 \right)$$

Equation 2

Where $C\_Gain_{b(T)}$ is the gain in consumption to discount segment b from premium segment a and $p_{a(T-1)}$ and $p_{a(T)}$ are the prices in segment a before and after T&T implementation. The gain in consumption in segment b is a loss in consumption in segment a, and thus $C\_Gain_{b(T)}$ needs to be subtracted from $C\_Prelim_{a(T)}$.There will be a similar shift in consumption from segment b to the illicit market, i. The gain in consumption in the illicit market needs to be subtracted from $C\_Prelim_{b(T)}$. This equation is derived from the standard formula for the arc cross-price elasticity of demand.

Equation 1 captures the reduction in the size of the cigarette market while Equation 2 captures shifts between the market segments (in response to relative price changes), including the shift from the cheapest legal segment into the illicit market.

In a market with multiple segments, total consumption post-T&T for the legal market segments (with the exception of the cheapest legal segment—to be discussed in point (4) below) is defined as:

$$C_{X(T)} = C\_Prelim_{X(T)} + C\_Gain_{X(T)} - C\_Gain_{Y(T)}$$

Equation 3

Where $C_{X(T)}$ is consumption in segment X post-T&T, $C\_Prelim_{X(T)}$ and $C\_Gain_{X(T)}$ are defined as given in Equation 1 and Equation 2, and $C\_Gain_{Y(T)}$ is the gain to the next cheapest segment (Y) from segment X. The highest-priced market segment will experience a loss equal to the gain in the next segment, but will experience no gain.

3) The size of the illicit market after T&T (I_T) will depend on various market shifts. First, the illicit market will reduce in size (to $C\_Prelim_{i(T)}$) as a result of the increase in the illicit price. Secondly, the illicit market could increase in size if prices in the cheapest legal segment go up and some of their consumers switch to the cheaper illicit cigarettes ($C\_Gain_{i(T)}$). Lastly, there will be a reduction in illicit consumption as T&T reduces the supply of illegal cigarettes, denoted as $I_{T\&T}$. These effects are summarised as follows:

$$I_T = C\_Prelim_{i(T)} + C\_Gain_{i(T)} - I_{T\&T}$$

Equation 4

$I_{T\&T}$ is dependent on l (the T&T effectiveness parameter), and is calculated as:

$$I_{T\&T} = \lambda\,(C\_Prelim_{i(T)} + C\_Gain_{i(T)})$$

Equation 5

Of $I_{T\&T}$—the portion of illicit trade that is prevented by T&T—some portion will be shifted back into the legal market ($I_{T\&T\_Legal}$). The remainder of $I_{T\&T}$ is effectively priced out of the market. This is because these smokers now face higher *legal* prices, and respond by either quitting or reducing daily consumption. This reduction in consumption is denoted as $I_{T\&T\_Reduce}$. The breakdown of $I_{T\&T}$ into now-legal consumption and reduced consumption is as follows:

$$I_{T\&T} = I_{T\&T\_Legal} + I_{T\&T\_Reduce}$$

Equation 6

It is assumed that $I_{T\&T\_Legal}$ is diverted into the cheapest legal segment (denoted *CS*), as this is the closest segment in terms of price that is available to these consumers. $I_{T\&T\_Legal}$ is therefore a function of ε_i, the price elasticity of demand for illicit consumers, $p_{CS(T)}$—the post-T&T price for the cheapest legal segment (the price these consumers will now face)—and $p_{i(T-1)}$, the pre-T&T illicit price (the price they previously faced). $I_{T\&T\_Legal}$ is defined as follows:

$$I_{T\&T\_Legal} = I_{T\&T} \times \frac{\left(1 + \varepsilon_i * {(p_{CS(T)} - p_{i(T-1)})}\big/{(p_{CS(T)} + p_{i(T-1)})}\right)}{\left(1 - \varepsilon_i * {(p_{CS(T)} - p_{i(T-1)})}\big/{(p_{CS(T)} + p_{i(T-1)})}\right)}$$

Equation 7

$I_{T\&T}$ is determined by Equation 5.

4) The cheapest legal market post-T&T, $C_{CS(T)}$ (special case of Equation 3) is therefore calculated as:

$$C_{CS(T)} = C\_Prelim_{CS(T)} + C\_Gain_{CS(T)} - C\_Gain_{i(T)} + I_{T\&T\_Legal}$$

Equation 8

5) We calculate the total revenue (from all tax sources, including excise, VAT, etc.) before and after T&T.

6) Lastly, we calculate the price of the T&T marker per pack, such that the additional revenue earned is equal to the total cost of the T&T system:

$$Marker = \frac{(Rev_T - Rev_{T-1})}{N_T}$$

Equation 9

Where Rev_{T-1} and Rev_T are the aggregate tax revenues from cigarettes pre- and post-T&T, $Marker$ is the T&T cost per pack and N_T is the total number of legal packs consumed in the post-T&T period. In this way, the model estimates the maximum price of a T&T solution per pack, i.e. additional tax that must be collected to cover the total cost of T&T, which is the break-even cost. Any T&T marker price lower than the break-even marker price will generate additional revenue for the government.

van der Zee K, *et al. Tob Control* 2022;0:1–6. doi: 10.1136/tc-2022-057550