Title: "*AJAE* Appendix: The Tariff Equivalent and Forgone Trade Effects of Prohibitive Technical Barriers to Trade"

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Note: The material contained herein is supplementary to the article named in the title and published in the American Journal of Agricultural Economics (*AJAE*).

Data appendix on apple flow data

Vector $\mathbf{x}_c = (x_{AUc}, x_{NZc}, x_{Otherc})$ represents per capita consumption of the three kinds of apples in any country c included in the data set. Vector x_{AUc} is per capita consumption of Australian apples in any country c (Bangladesh, Barbados, etc…) which consumes Australian apples. This grouping allows us to identify the relative preferences between Australian and New Zealand apples and the tariff equivalent of the policies affecting the potential flow of New Zealand apples to Australia. To clarify further, x_{AUAU} is simply the per capita consumption of the domestic apples in Australia, and x_{NZAU} is the per capita consumption of New Zealand apple in Australia which is zero. Similarly, x_{NZNZ} is the per capita consumption of domestic apples in New Zealand.

Aggregate fresh apple consumption data come from FAO. Per capita consumption of the three apple types in a country is defined as follows: x_{AUc} is the bilateral flow of Australian apples to that country c (for $c \neq$ Australia) normalized by its population; In Australia, x_{AUAU} is the total consumption of domestic apples normalized by Australian population. Variable x_{NZc} is a flow of New Zealand apples to country c normalized by c's population ($c \neq$ New Zealand). In New Zealand, x_{NZNZ} is the total consumption of domestic apples normalized by New Zealand's population. Last, x_{Otherc} is aggregate consumption of apple in country c minus the sum of Australian and New Zealand apples flows to country c, also normalized by c's population. In Australia and New Zealand, domestic consumption of domestic apples is defined as the aggregate apple consumption of the respective country minus total imported apples, then normalized by respective population to be expressed in a per capita basis. Per capita consumption of other apples in these two countries ($x_{OtherAU}$ and $x_{OtherNZ}$) is defined as their respective total imports normalized by their population since neither Australia nor New Zealand do trade apples with each other.

Technical appendix on the methodology

1.The log-likelihood function specification is (for observations *i*=1…N)

(A1.1) $$g^i_{NZ}(\mathrm{x},\mathrm{y},\mathrm{wp},\mathrm{d},\mathrm{t};\mathrm{TBT},\delta,\omega,g,\eta) = \ln\left[v'(AOG)(wp^i_{NZ}+g\,d^i_{NZ})(1+t^i_{NZ}+TBT^i_{NZ})(x^i_{NZ}+w_{NZ})\right]-d_{NZ}-\eta_{NZ}\mathrm{y}^i_{NZ},$$

(A1.2) $$g^i_{AU}(\mathrm{x},\mathrm{y},\mathrm{wp},\mathrm{d},\mathrm{t};\mathrm{TBT},\delta,\omega,g,\eta) = \ln\left[v'(AOG)(p^i_{AU}+g\,d^i_{AU})(1+t^i_{AU}+TBT^i_{AU})(x^i_{AU}+w_{AU})\right]-d_{AU}-\eta_{AU}\mathrm{y}^i_{AU},$$

(A1.3) $$g^i_{Other}(\mathrm{x},\mathrm{y},\mathrm{wp},\mathrm{d},\mathrm{t};\mathrm{TBT},\delta,\omega,g,\eta) = \ln\left[v'(AOG)(p^i_{Other}+g\,d^i_{Other})(1+t^i_{Other}+TBT^i_{Other})(x^i_{Other}+w_{AU})\right]-d_{Other}-\eta_{Other}\mathrm{y}^i_{Other}.$$

For observations *i*=1…N, we have

(A 2.1) $$X^i_{NZ} = \begin{cases} f(g^i_{NZ})*\left|J^i_{NZ}\right| & if\ x^i_{NZ}>0 \\ \Phi(g^i_{NZ}) & if\ x^i_{NZ}=0 \end{cases},$$

(A2.2) $$X^i_{AU} = \begin{cases} f(g^i_{AU})*\left|J^i_{AU}\right| & if\ x^i_{AU}>0 \\ \Phi(g^i_{AU}) & if\ x^i_{AU}=0 \end{cases},$$

(A2.3) $$X^i_{Other} = \begin{cases} f(g^i_{Other})*\left|J^i_{Other}\right| & if\ x^i_{Other}>0 \\ \Phi(g^i_{Other}) & if\ x^i_{Other}=0 \end{cases},$$

where $\left|J^i_{NZ}\right|$ is the absolute value of the Jacobian for the transformation from g^i_{NZ} to x^i_{NZ}; $\left|J^i_{AU}\right|$ is the absolute value of the Jacobian for the transformation from g^i_{AU} to x^i_{AU}; $\left|J^i_{Other}\right|$ is the absolute value of the Jacobian for the transformation from g^i_{Other} to x^i_{Other}; f is the density function of standard normal distribution; and Φ is the cumulative density function of standard normal distribution.

The log-likelihood function is

(A3) $$l=\sum_{i=1}^{N}\ln(X^i_{NZ}X^i_{AU}X^i_{Other}) .$$

2. The algorithm to calculate the increase in imports $x_{NZ}^{(i,j)}$, producer surplus $PS^{(i,j)}$ and compensating variation $CV^{(i,j)}$ after the elimination of SPS measures is as follows in steps (1)-(4).

We define:

$$a_{NZ}^{(i,j)} = \exp(h_{NZ}^{(i)} * y_{AU} + d_{NZ}^{(i)} + e_{NZ}^{(j)}),$$

(A4)
$$a_{AU}^{(i,j)} = \exp(h_{AU}^{(i)} * y_{AU} + d_{AU}^{(i)} + e_{AU}^{(j)}),$$

$$a_{Other}^{(i,j)} = \exp(h_{Other}^{(i)} * y_{AU} + d_{Other}^{(i)} + e_{Other}^{(j)}).$$

(1) Solve for the new Australian domestic price p_{AU}^{new} where demand equals supply of Australian apples:

(A5) $$X_{AUAU}^{(i,j)} = S_{AU}(p_{AU}^{new}, u^{new})$$

where $x_{AUAU}^{(i,j)} = \dfrac{(I-AOG)a_{AU}^{(i,j)} - p_{AU}^{new} w_{AU}^{(i)}(a_{NZ}^{(i,j)} + a_{Other}^{(i,j)}) + a_{AU}^{(i,j)}(w_{NZ}^{(i)} p_{NZ} + w_{Other}^{(i)} p_{Other})}{p_{AU}^{new}(a_{NZ}^{(i,j)} + a_{AU}^{(i,j)} + a_{Other}^{(i,j)})}$ and

$X_{AUAU}^{(i,j)} = x_{AUAU}^{(i,j)} *$ population, $S_{AU}(p_{AU}^{new}, u^{new})$ is defined in equation (13); $(I-AOG)$ is Australian per capita expenditure on apples; and $u^{new} = u$ if there is no disease transmission and $u^{new} < u$ if there is disease transmission. Since there is no explicit solution, we used numerical bisection method to solve for p_{AU}^{new}. The bisection method is illustrated in the calculation of $\boldsymbol{CV}^{(i,j)}$.

(2) Calculate the increase in imports of NZ apples in Australia:

(A6) $$x_{NZAU}^{(i,j)} = \frac{(I-AOG)a_{NZ}^{(i,j)} - p_{NZ} w_{NZ}^{(i)}(a_{AU}^{(i,j)} + a_{Other}^{(i,j)}) + a_{NZ}^{(i,j)}(p_{AU}^{new} w_{AU}^{(i)} + p_{Other} w_{Other}^{(i)})}{p_{NZ}(a_{NZ}^{(i,j)} + a_{AU}^{(i,j)} + a_{Other}^{(i,j)})}$$

(3) Calculate the producers' surplus.

(A7) $$PS^{(i,j)} = u\, p_{AU}^{(1+w_s)} / (1+e_s) - u^{new} p_{AU}^{new(1+w_s)} / (1+e_s)$$

(4) Calculate the $\boldsymbol{CV}^{(i,j)}$ using numerical bisection method.

3. The numerical bisection method is a root finding algorithm. This algorithm repeatedly divides an interval in half and then selects the sub-interval in which a root exists. To solve for the $\boldsymbol{CV}^{(i,j)}$ in step (3) on page 19, the function we have is

(A8) $$\boldsymbol{f}(\boldsymbol{CV}^{(i,j)}(\mathbf{p}^0, \mathbf{p}^1, \boldsymbol{I}, \mathbf{y}; m^{(i)}, \boldsymbol{\varepsilon}^{(j)})) = \boldsymbol{V}(\mathbf{p}^0, \boldsymbol{I}, \mathbf{y}; m^{(i)}, \boldsymbol{\varepsilon}^{(j)}) - \boldsymbol{V}(\mathbf{p}^1, \boldsymbol{I} - \boldsymbol{CV}^{(i,j)}(\mathbf{p}^0, \mathbf{p}^1, \boldsymbol{I}, \mathbf{y}; m^{(i)}, \boldsymbol{\varepsilon}^{(j)}), \mathbf{y}; m^{(i)}, \boldsymbol{\varepsilon}^{(j)}),$$

where $\boldsymbol{V}$ is the indirect utility function obtained from maximizing the utility function defined in equation (1) and $\boldsymbol{V}$ is nonlinear in $\boldsymbol{CV}^{(i,j)}$. There is no explicit solution to $\boldsymbol{f}(\boldsymbol{CV}^{(i,j)})$=0, therefore we use the numerical bisection method. The steps are as follows:

(1) Find the interval where the solution of $\boldsymbol{f}(\boldsymbol{CV}^{(i,j)})$=0 lies in. When there is no compensating variation, i.e., $\boldsymbol{CV}^{(i,j)}$=0, we have $\boldsymbol{f}$(0)>0; find a $\boldsymbol{CV}_{\max}{}^{(i,j)}$, where $\boldsymbol{f}(\boldsymbol{CV}_{\max}{}^{(i,j)})$ <0. $\boldsymbol{CV}_{\max}{}^{(i,j)}$ is generally set to be a large value. Then the first interval is [0, $\boldsymbol{CV}_{\max}{}^{(i,j)}$], and we have $\boldsymbol{f}$(0)* $\boldsymbol{f}(\boldsymbol{CV}_{\max}{}^{(i,j)})$ <0;

(2) Divide the interval in two by computing c=0.5*(0+$\boldsymbol{CV}_{\max}{}^{(i,j)}$)=0.5$\boldsymbol{CV}_{\max}{}^{(i,j)}$. The two intervals are [0,c] and [c, $\boldsymbol{CV}_{\max}{}^{(i,j)}$]. There are two possibilities: either $\boldsymbol{f}$(0)* $\boldsymbol{f}$(c) <0 or $\boldsymbol{f}$(c)* $\boldsymbol{f}(\boldsymbol{CV}_{\max}{}^{(i,j)})$ <0; if $\boldsymbol{f}$(0)* $\boldsymbol{f}$(c)<0, then the next sub-interval where the root lies in is [0,c], otherwise if $\boldsymbol{f}$(c)* $\boldsymbol{f}(\boldsymbol{CV}_{\max}{}^{(i,j)})$ <0 then the next sub-interval where the root lies in is [c, $\boldsymbol{CV}_{\max}{}^{(i,j)}$].

(3) Repeat (4.2) to the sub-intervals with ***f(x)*** having opposite signs until the length of the interval is less than the tolerance level set. The solution is approximated by the mid point of the last sub-interval before the tolerance level is reached.