Supplementary Appendix to
Trade in Agricultural and Food Products

Carl Gaigné*[1,2] Christophe Gouel†[3,4]

[1]INRAE, UMR 1302 SMART, 4 Allée Adolphe Bopierre, CS 61103, 35011 Rennes cedex, France
[2]CREATE, Laval University, 2425 Rue de l'Agriculture, Quebec City, QC, Canada
[3]Université Paris-Saclay, INRAE, AgroParisTech, PSAE, 78850, Thiverval-Grignon, France
[4]CEPII, 20 avenue de Ségur, 75007, Paris, France

This online appendix provides the technical derivations of theoretical results associated with welfare changes in sections 4 and 5.

A Welfare changes in Ricardian model with inputs

To simplify the calculations, we have made a few simplifying assumptions that we restate here. Since we focus on agricultural products, we have assumed that food and the outside good are homogeneous goods produced from labor only by homogeneous firms under perfect competition (i.e., no selection mechanism: $\hat{Z}^F_{jj} = 1$ and $\hat{Z}^O_{jj} = 1$). From equation (10), we need the expression of $\hat{P}^A_{jj}$, $\hat{P}^F_{jj}$, $\hat{P}^O_j$, and $\hat{R}_j$. We use equation (11) with $\hat{Z}^A_{jj} = \hat{\mathcal{Z}}^A_j (\hat{\lambda}^A_{jj})^{1/(\varepsilon^A-1)-1/\varkappa^A}$ and we maintain constant potential productivity when analyzing gains from trade (i.e., $\hat{\mathcal{Z}}^A_j = 1$) to obtain the following welfare formula:

$$\ln \hat{V}_j = -\frac{\beta^A_j}{\varkappa^A} \ln \hat{\lambda}^A_{jj} - \beta^A_j \ln \hat{c}^A_j - \frac{\beta^F_j}{\varepsilon^F - 1} \ln \hat{\lambda}^F_{jj} - \beta^F_j \ln \hat{c}^F_j + \ln \left[\hat{R}_j \left(\hat{P}^O_j \right)^{-\beta^O_j} \right]. \tag{A1}$$

Our assumptions about the food and outside good markets imply $P^k_j = (\lambda^k_{jj})^{1/(\varepsilon^k-1)} w^{\text{labor}}_j$ with $k = F, O$. Plugging the expressions of c^A_j and P^O_j into the trade share equation (15) yields

$$\hat{P}^A_j = \left(\hat{w}^{\text{land}}_j\right)^{\gamma^{A,\text{land}}_j} \left(\hat{w}^{\text{labor}}_j\right)^{\gamma^{A,\text{labor}}_j} \left(\hat{P}^A_j\right)^{\gamma^{A,A}_j} \left(\hat{P}^F_j\right)^{\gamma^{A,F}_j} \left(\hat{P}^O_j\right)^{\gamma^{A,O}_j} \left(\hat{\lambda}^A_{jj}\right)^{-1/\varkappa^A}, \tag{A2}$$

$$= \left(\hat{w}^{\text{labor}}_j\right)^{1-\tilde{\gamma}^{A,\text{land}}_j} \left(\hat{w}^{\text{land}}_j\right)^{\tilde{\gamma}^{A,\text{land}}_j} \left(\hat{\lambda}^A_{jj}\right)^{1/[\varkappa^A(1-\gamma^{A,A}_j)]} \left(\hat{\lambda}^F_{jj}\right)^{\tilde{\gamma}^{A,F}_j/(\varepsilon^F-1)} \left(\hat{\lambda}^O_{jj}\right)^{\tilde{\gamma}^{A,O}_j/(\varepsilon^O-1)}, \tag{A3}$$

with $\tilde{\gamma}^{A,\text{labor}}_j \equiv \gamma^{A,\text{labor}}_j/(1-\gamma^{A,A}_j)$, $\tilde{\gamma}^{A,\text{land}}_j \equiv \gamma^{A,\text{land}}_j/(1-\gamma^{A,A}_j)$, $\tilde{\gamma}^{A,F}_j \equiv \gamma^{A,F}_j/(1-\gamma^{A,A}_j)$ and $\tilde{\gamma}^{A,O}_j \equiv \gamma^{A,O}_j/(1-\gamma^{A,A}_j)$. Note that we have $\tilde{\gamma}^{A,\text{labor}}_j + \tilde{\gamma}^{A,\text{land}}_j + \tilde{\gamma}^{A,F}_j + \tilde{\gamma}^{A,O}_j = 1$. As we consider more than one factor of production, the price index now depends also on changes in relative factor prices, which affects production costs across sectors. More trade in intermediates used in agricultural production (lower λ^k_{jj} with $k = A, F$ or λ^O_{jj}) leads to a decline in the price index of agricultural products, which implies additional welfare gains. In addition, given import shares, trade gains are greater

*carl.gaigne@inrae.fr
†christophe.gouel@inrae.fr

the larger the share of intermediates ($\gamma_j^{A,F}$ and $\gamma_j^{A,O}$). As a consequence, the introduction of tradable inputs magnifies the gains from trade.

Then we can simplify the unit costs:

$$\hat{c}_j^A = \left(\hat{w}_j^{\text{labor}}\right)^{\gamma_j^{A,\text{labor}}} \left(\hat{w}_j^{\text{land}}\right)^{\gamma_j^{A,\text{land}}} \left(\hat{P}_j^A\right)^{\gamma_j^{A,A}} \left(\hat{P}_j^F\right)^{\gamma_j^{A,F}} \left(\hat{P}_j^O\right)^{\gamma_j^{A,O}}, \tag{A4}$$

$$= \left(\hat{w}_j^{\text{labor}}\right)^{\gamma_j^{A,\text{labor}}+\gamma_j^{A,F}+\gamma_j^{A,O}} \left(\hat{w}_j^{\text{land}}\right)^{\gamma_j^{A,\text{land}}} \left(\hat{P}_j^A\right)^{\gamma_j^{A,A}} \left(\hat{\lambda}_{jj}^F\right)^{\gamma_j^{A,F}/(\varepsilon^F-1)} \left(\hat{\lambda}_{jj}^O\right)^{\gamma_j^{A,O}/(\varepsilon^O-1)}, \tag{A5}$$

$$= \left(\hat{w}_j^{\text{labor}}\right)^{\tilde{\gamma}_j^{A,\text{labor}}+\tilde{\gamma}_j^{A,F}+\tilde{\gamma}_j^{A,O}} \left(\hat{w}_j^{\text{land}}\right)^{\tilde{\gamma}_j^{A,\text{land}}} \left(\hat{\lambda}_{jj}^A\right)^{\tilde{\gamma}_j^{A,A}/\varkappa^A} \left(\hat{\lambda}_{jj}^F\right)^{\tilde{\gamma}_j^{A,F}/(\varepsilon^F-1)} \left(\hat{\lambda}_{jj}^O\right)^{\tilde{\gamma}_j^{A,O}/(\varepsilon^O-1)}, \tag{A6}$$

$$= \hat{w}_j^{\text{labor}} \left(\hat{\omega}_j\right)^{\tilde{\gamma}_j^{A,\text{land}}} \left(\hat{\lambda}_{jj}^A\right)^{\tilde{\gamma}_j^{A,A}/\varkappa^A} \left(\hat{\lambda}_{jj}^F\right)^{\tilde{\gamma}_j^{A,F}/(\varepsilon^F-1)} \left(\hat{\lambda}_{jj}^O\right)^{\tilde{\gamma}_j^{A,O}/(\varepsilon^O-1)}, \tag{A7}$$

where $\hat{\omega}_j = \hat{w}_j^{\text{land}}/\hat{w}_j^{\text{labor}}$.

The change in total income is

$$\hat{R}_j = \hat{w}_j^{\text{labor}}[\hat{\omega}_j s_j + (1 - s_j)],$$

where s_j is the share of land income in total income.

All these elements lead to the following expression of welfare changes

$$\ln \hat{V}_j = -\frac{\beta_j^A\left(1+\tilde{\gamma}_j^{A,A}\right)}{\varkappa^A} \ln \hat{\lambda}_{jj}^A - \frac{\beta_j^F + \beta_j^A \tilde{\gamma}_j^{A,F}}{\varepsilon^F - 1} \ln \hat{\lambda}_{jj}^F - \frac{\beta_j^A \tilde{\gamma}_j^{A,O}}{\varepsilon^O - 1} \ln \hat{\lambda}_{jj}^O + \ln g(\hat{\omega}_j), \tag{A8}$$

with $g(\hat{\omega}_j) = [\hat{\omega}_j s_j + (1 - s_j)]\hat{\omega}_j^{-\beta_j^A \tilde{\gamma}_j^{A,\text{land}}}$.

Using $w_j^{\text{labor}} L_j^k = \gamma_j^{k,\text{labor}} Y_j^k$ and $w_j^{\text{land}} \mathcal{L}_j^k = \gamma_j^{k,\text{land}} Y_j^k$ where L_j^k (resp., $\mathcal{L}_j^k$) is the mass of labor (resp., land) in j allocated in sector k, labor and land markets clearing conditions in the counterfactual equilibrium imply $w_j^{\text{labor}'} L_j = \sum_k w_j^{\text{labor}} L_j^k \hat{Y}_j^k$ and $w_j^{\text{land}'} \mathcal{L}_j = \sum_k w_j^{\text{land}} \mathcal{L}_j^k \hat{Y}_j^k$. Dividing these equalities by $w_j^{\text{labor}} L_j$ (resp., $w_j^{\text{land}} \mathcal{L}_j$) yields

$$\hat{w}_j^{\text{labor}} = \hat{Y}_j \left(\sum_k \hat{\mu}_j^k s_j^{k,\text{labor}} + \hat{\mu}_j^O s_j^{O,\text{labor}}\right) \text{ and } \hat{w}_j^{\text{land}} = \hat{Y}_j \hat{\mu}_j^A, \tag{A9}$$

where $\mu_j^k = Y_j^k / Y_j$ (resp. $\mu_j^O = Y_j^O$) denotes the share of total revenues in country j generated from sector k (resp. from the aggregate outside good) and $s_j^{k,\text{labor}}$ is the share of labor income from sector k in total labor income. Therefore,

$$\hat{\omega}_j = \frac{\hat{\mu}_j^A}{\sum_k \hat{\mu}_j^k s_j^{k,\text{labor}} + \hat{\mu}_j^O s_j^{O,\text{labor}}}.$$

In addition, under autarky, $\beta_j^A R_j = (1 - \gamma_j^{A,A})\mu_j^A Y_j$ and $Y_j = R_j + (\gamma_j^{A,A} + \gamma_j^{A,F} + \gamma_j^{A,O})\mu_j^A Y_j$ imply $\mu_j^A = \beta_j^A/[1 - \gamma_j^{A,A} + \beta_j^A(\gamma_j^{A,A} + \gamma_j^{A,F} + \gamma_j^{A,O})]$, $\mu_j^O = \mu_j^A \gamma_j^{A,O} + \beta_j^O R_j / Y_j$ with $R_j/Y_j = (1 - \gamma_j^{A,A})\mu_j^A/\beta_j^A$, and $\mu_j^F = \mu_j^A \gamma_j^{A,F} + \beta_j^F R_j / Y_j$. It is straightforward to check that $\mu_j^A + \mu_j^F + \mu_j^O = 1$.

B Welfare changes in model with monopolistic competition and inputs

To compute welfare, we first determine the change in Z_{jj}^k, the parameter capturing the selection mechanisms, which combines an entry effect and a selection effect. Indeed, equation (26) implies

$$\ln \hat{Z}_{jj}^k = \ln \hat{\mathcal{M}}_j^k / \left(\varepsilon^k - 1\right) + \ln \hat{z}_{jj}^k,$$

where $\hat{\mathcal{M}}_j^k$ is the change to the mass of surviving domestic firms (the entry effect). The mass of entering firms is given by free entry condition which ensures that aggregate profits (gross of entry costs) exactly cover the aggregate entry cost $\mathcal{M}_j^{k,e} c_j^k \mathcal{F}_j^{k,e}$. As firm-level productivity is Pareto distributed, aggregate profits are a constant share $\tilde{\pi}^k$ of aggregate revenues Y_j^k where $\tilde{\pi}^k$ is a bundle of parameters (h^k and ε^k as in the MC model as well as Λ^k, ρ^k, and η^k since we consider vertical differentiation) so that $\tilde{\pi}^k Y_j^k = \mathcal{M}_j^{k,e} c_j^k \mathcal{F}_j^{k,e}$. Since $\mathcal{M}_j^k = \mathcal{M}_j^{k,e}(\underline{z}_j^k / z_{jj}^k)^{h^k} = \tilde{\pi}^k Y_j^k (\underline{z}_j^k / z_{jj}^k)^{h^k} / (c_j^k \mathcal{F}_j^{k,e})$, the change in the mass of surviving firms (or domestic varieties) is

$$\hat{\mathcal{M}}_j^k = \hat{Y}_j^k \left(\hat{z}_{jj}^k\right)^{-h^k} / \hat{c}_j^k. \tag{B1}$$

In addition, $\mathcal{M}_j^k = X_{jj}^k / \bar{x}_{jj}^k$ where $\bar{x}_{jj}^k$ and X_{jj}^k correspond to average domestic sales of firms and aggregate expenditure on domestic varieties, respectively. Using $X_{jj}^k = \lambda_{jj}^k E_j^k$ and equation (27), we have $\hat{X}_{jj}^k = \hat{\lambda}_{jj}^k \hat{E}_j^k$ and $\hat{\bar{x}}_{jj}^k = \hat{c}_j^k$. As a consequence,

$$\hat{\mathcal{M}}_j^k = \hat{E}_j^k \left(\hat{\lambda}_{jj}^k\right) / \hat{c}_j^k. \tag{B2}$$

Hence, combining equation (B1) and equation (B2) yields

$$\ln \hat{z}_{jj}^k = \frac{1}{h^k}\left[-\ln \hat{\lambda}_{jj}^k + \ln(\hat{Y}_j^k / \hat{E}_j^k)\right], \tag{B3}$$

and

$$\ln \hat{\mathcal{M}}_j^k = \ln \hat{\lambda}_{jj}^k + \ln \hat{E}_j^k - \ln \hat{c}_j^k. \tag{B4}$$

Inserting equation (B4) in equation (10) leads to

$$\ln \hat{V}_j = -\sum_{k=1}^{K} \frac{\beta_j^k}{\varepsilon^k - 1} \ln \hat{\lambda}_{jj}^k - \sum_{k=1}^{K} \beta_j^k \ln \hat{c}_j^k + \sum_{k=1}^{K} \frac{\beta_j^k}{\varepsilon^k - 1} \ln \hat{\mathcal{M}}_j^k + \sum_{k=1}^{K} \beta_j^k \ln \hat{z}_{jj}^k + \ln \hat{R}_j, \tag{B5}$$

$$= -\sum_{k=1}^{K} \beta_j^k m^k \ln \hat{c}_j^k + \sum_{k=1}^{K} \frac{\beta_j^k}{\varepsilon^k - 1} \ln \hat{E}_j^k + \sum_{k=1}^{K} \beta_j^k \ln \hat{z}_{jj}^k + \ln \hat{R}_j, \tag{B6}$$

where $m^k = \varepsilon^k / (\varepsilon^k - 1)$. Note that, if all producers use labor and no inputs and the share of expenditure on domestic varieties of the aggregate outside good is kept constant so that $P_j^O = \hat{w}^{\text{labor}}$ (the products of the aggregate outside good are produced by homogeneous firms under perfect competition), then $\hat{E}_j^k = \hat{R}_j = \hat{w}_j^{\text{labor}}$ and $\ln \hat{V}_j = \sum_{k=1}^{K} \beta_j^k \ln \hat{z}_{jj}^k$ as $\sum_{k=1}^{K} \beta_j^k + \beta_j^O = 1$.

Consider now that production of processed food combines labor, processed food products, and agricultural primary products where $c_j^F = (w_j^{\text{labor}})^{\gamma_j^{F,\text{labor}}} (P_j^F)^{\gamma_j^{F,F}} (P_j^A)^{\gamma_j^{F,A}}$ with $\gamma_j^{F,\text{labor}} + \gamma_j^{F,F} + \gamma_j^{F,A} = 1$. Because $\hat{P}_j^F = (\hat{\lambda}_{jj}^F)^{1/(\varepsilon^F - 1)} \hat{c}_j^F / \hat{Z}_{jj}^F$, we have

$$\hat{P}_j^F = (\hat{\lambda}_{jj}^F)^{1/(\varepsilon^F - 1)} \hat{c}_j^F (\hat{\lambda}_{jj}^F)^{1/(1-\varepsilon^F)} (\hat{E}_j^k)^{1/(1-\varepsilon^F)} (\hat{c}_j^F)^{1/(\varepsilon^F - 1)} / \hat{z}_{jj}^F, \tag{B7}$$

$$= (\hat{c}_j^F)^{m^F} (\hat{E}_j^k)^{1/(1-\varepsilon^F)} / \hat{z}_{jj}^F. \tag{B8}$$

In addition, agricultural production is assumed to use only labor and to operate under perfect competition so that $\hat{P}_j^A = (\hat{\lambda}_{jj}^A)^{1/\varkappa^A} \hat{w}_j^{\text{labor}}$ according to equation (15) ($\mathcal{Z}_j^A$ is kept constant). Hence, the unit cost can be rewritten as follows

$$\hat{c}_j^F = (w_j^{\text{labor}})^{\frac{1-\gamma_j^{F,F}}{1-m^F \gamma_j^{F,F}}} (\hat{E}_j^k)^{\frac{-\gamma_j^{F,F}}{(\varepsilon^F - 1)(1-m^F \gamma_j^{F,F})}} (\hat{z}_{jj}^F)^{\frac{-\gamma_j^{F,F}}{1-m^F \gamma_j^{F,F}}} (\hat{\lambda}_{jj}^A)^{\frac{\gamma_j^{F,A}}{\varkappa^A (1-m^F \gamma_j^{F,F})}}. \tag{B9}$$

The welfare change (10) associated with a move to food autarky when food sector operates under monopolistic competition and uses agricultural and food products as intermediate inputs becomes

$$\ln \hat{V}_j = -\frac{\beta_j^A}{\varkappa^A} \ln(\hat{\lambda}_{jj}^A) - (\beta_j^A + \beta_j^O) \ln \hat{w}_j^{\text{labor}} - \beta_j^F m^k \ln \hat{c}_j^F + \frac{\beta_j^F}{\varepsilon^F - 1} \ln \hat{E}_j^F + \beta_j^F \ln \hat{z}_{jj}^F + \ln \hat{R}_j, \tag{B10}$$

$$= -\frac{1}{\varkappa^A} \left(\beta_j^A + \beta_j^F \frac{\gamma_j^{F,A} m^F}{1 - \gamma_j^{F,F} m^F} \right) \ln \hat{\lambda}_{jj}^A + \left(1 + \frac{\gamma_j^{F,F} m^F}{1 - \gamma_j^{F,F} m^F} \right) \ln \hat{z}_{jj}^F + \ln \hat{g}_j. \tag{B11}$$

with

$$\ln \hat{g}_j = -(\beta_j^A + \beta_j^O) \ln \hat{w}_j^{\text{labor}} - \beta_j^F \frac{(1 - \gamma_j^{F,F}) m^k}{1 - m^F \gamma_j^{F,F}} \ln \hat{w}_j^{\text{labor}} + \frac{\beta_j^F \gamma_j^{F,F} m^F}{(\varepsilon^F - 1)(1 - m^F \gamma_j^{F,F})} \hat{E}_j^k + \frac{\beta_j^F}{\varepsilon^F - 1} \ln \hat{E}_j^F + \ln \hat{R}_j, \tag{B12}$$

$$= -(\beta_j^A + \beta_j^O) \ln \hat{w}_j^{\text{labor}} - \beta_j^F \left[\frac{(1 - \gamma_j^{F,F}) m^k}{1 - m^F \gamma_j^{F,F}} \ln \hat{w}_j^{\text{labor}} - \frac{1}{(\varepsilon^F - 1)(1 - m^F \gamma_j^{F,F})} \ln \hat{E}_j^k \right] + \ln \hat{R}_j, \tag{B13}$$

$$= -(\beta_j^A + \beta_j^O) \ln \hat{w}_j^{\text{labor}} - \beta_j^F \left[\frac{(1 - \gamma_j^{F,F}) m^k}{1 - m^F \gamma_j^{F,F}} - \frac{1}{(\varepsilon^F - 1)(1 - m^F \gamma_j^{F,F})} \right] \ln \hat{w}_j^{\text{labor}} + \ln \hat{R}_j, \tag{B14}$$

as $\hat{E}_j^k = \hat{w}_j^{\text{labor}}$. Because $m^F = \varepsilon^F / (\varepsilon^F - 1)$, we have

$$\frac{(1 - \gamma_j^{F,F}) m^k}{1 - m^F \gamma_j^{F,F}} - \frac{1}{(\varepsilon^F - 1)(1 - m^F \gamma_j^{F,F})} = \frac{\varepsilon^F - 1 - \gamma_j^{F,F} \varepsilon^F}{(\varepsilon^F - 1)(1 - m^F \gamma_j^{F,F})}, \tag{B15}$$

$$= \frac{1 - m^F \gamma_j^{F,F}}{1 - m^F \gamma_j^{F,F}}, \tag{B16}$$

$$= 1. \tag{B17}$$

Hence, equation (B12) becomes

$$\ln \hat{g}_j = -(\beta_j^A + \beta_j^O) \ln \hat{w}_j^{\text{labor}} - \beta_j^F \ln w_j^{\text{labor}} + \ln \hat{R}_j, \tag{B18}$$

$$= 0. \tag{B19}$$

as $\hat{R}_j = \hat{w}_j^{\text{labor}}$ and $\beta_j^A + \beta_j^A + \beta_j^O = 1$. As a result, equation (B10) becomes

$$\ln \hat{V}_j = -\frac{1}{\varkappa^A} \left(\beta_j^A + \beta_j^F \frac{\gamma_j^{F,A} m^F}{1 - \gamma_j^{F,F} m^F} \right) \ln \hat{\lambda}_{jj}^A + \left(1 + \frac{\gamma_j^{F,F} m^F}{1 - \gamma_j^{F,F} m^F} \right) \ln \hat{z}_{jj}^F, \tag{B20}$$

that corresponds to equation (31).