Mémoire M2

L'impact des politiques publiques sur les émissions de gaz à effet de serre dans le secteur agricole au travers des échanges commerciaux.

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Chapter 1

Introduction

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We will study in this paper the effect of public policies in agriculture and their effects on greenhouse gaz emissions throughout trade.

[Biblio]

Section 2 presents a simple two-country model that examines the implementation of two agricultural public policies: the introduction of tariffs and the provision of production subsidies. The objective is to assess their impacts on greenhouse gas emissions through price equilibria, offering initial insights into how these policies may affect total emissions.

Section 3 goes further by introducing a partial equilibrium model that incorporates multiple countries and production sectors. This model builds on the studies of Gouel and Laborde (2021) and Gouel (2025). However, rather than using a Frechet distribution to capture heterogeneity in the yield function, it employs a multilogit management function—with costs that increase with specialization—and represents yield using an isoelastic function, following Galichon (2016).

Section 4 details the calibration of the model, utilizing data from FABIO and FAOSTAT.

Chapter 2

Intuition

This section offers preliminary insights into how greenhouse gas (GHG) emissions respond to the implementation of two agricultural public policies: the introduction of tariffs and the provision of subsidies.

To do so we consider two countries market, with a home importing country H, and a foreign exporting country F.

We denote the supply and demand functions for both countries, with country $i \in \{H, F\}$, as follows:

$$S_i = S_i^0 \left(1 + \eta_i \frac{P_i - P_i^0}{P_i^0}\right), \qquad D_i = D_i^0 \left(1 + \epsilon_i \frac{P_i - P_i^0}{P_i^0}\right),$$

where S_i and D_i are the quantities produced and demanded by country i, P_i is the price in country i, and η_i and ϵ_i are the supply and demand elasticities in country i, respectively. Here, X^0 denotes the initial value of X.

Since these two countries comprise the entire economy, the difference between domestic demand and production in one country equals the difference between production and demand in the other:

$$D_H - S_H = S_F - D_F.$$

For simplicity, we introduce the following aggregate elasticities:
- Total demand elasticity

$$\epsilon = \frac{\partial D}{\partial P_F} \frac{P_F^0}{D^0} = \left(\epsilon_H \frac{D_H^0}{P_H^0} + \epsilon_F \frac{D_F^0}{P_F^0}\right) \frac{P_F^0}{D^0} < 0,$$

- Total supply elasticity

$$\eta = \frac{\partial S}{\partial P_F} \frac{P_F^0}{S^0} = \left(\eta_H \frac{S_H^0}{P_H^0} + \eta_F \frac{S_F^0}{P_F^0}\right) \frac{P_F^0}{S^0} > 0,$$

- Home import demand elasticity

$$\mu_H = \frac{\partial (D_H - S_H)}{\partial P_H} \frac{P_H^0}{M_H^0} = \frac{\epsilon_H D_H^0 - \eta_H S_H^0}{M_H^0} < 0,$$

- Foreign export supply elasticity

$$\chi_F = \frac{\partial (S_F - D_F)}{\partial P_F} \frac{P_F^0}{X_F^0} = \frac{\eta_F S_F^0 - \epsilon_F D_F^0}{X_F^0} > 0.$$

For each policy, we examine its effects on total emissions through its impact on international prices (foreign prices) and total production.

2.1 Introduction of a tariff in the home country

Consider the first policy, where country H introduces a tariff t. This implies the following relation between prices:

$$P_H = P_F + t.$$

Under the tariff, the price in the exporting country becomes

$$\frac{P_F}{P_F^0} = -\frac{\mu_H(1 - t/P_H^0) - \chi_F}{\eta - \epsilon} \frac{X_F^0}{D^0},$$

and it varies negatively with t:

$$\frac{\partial P_F}{\partial t} = \frac{\mu_H}{\eta - \epsilon} \frac{X_F^0}{D^0} \frac{P_F^0}{P_H^0} < 0.$$

The total production from both countries is given by

$$Q = S_H^0 + S_F^0 + \frac{(P_H^0 - P_F^0 - t)(S_H^0 \eta_H \chi_F + S_F^0 \eta_F \mu_H)}{P_F^0 \mu_H - P_H^0 \chi_F},$$

and thus varies according to

$$\frac{\partial Q}{\partial t} = \frac{S_H^0 \eta_H \chi_F + S_F^0 \eta_F \mu_H}{P_F^0 \mu_H - P_H^0 \chi_F}.$$

The sign of this change is determined by that of $S_H^0 \eta_H \chi_F + S_F^0 \eta_F \mu_H$. There is no clear effect of a tariff increase on total production: a first (direct) effect increases home production, while a second (indirect) effect decreases global production because of lower foreign prices.

Concerning global emissions E, if we consider emissions as the product of the quantity produced and an emission factor, we obtain:

$$E = E^0 + \frac{(P_H^0 - P_F^0 - t)(E_H^0 \eta_H \chi_F + E_F^0 \eta_F \mu_H)}{P_F^0 \mu_H - P_H^0 \chi_F},$$

and thus

$$\frac{\partial E}{\partial t} = \frac{E_H^0 \eta_H \chi_F + E_F^0 \eta_F \mu_H}{P_F^0 \mu_H - P_H^0 \chi_F}.$$

Here, the sign is the same as that of $E_H^0 \eta_H \chi_F + E_F^0 \eta_F \mu_H$. In other words, the effect of increasing the tariff on global emissions is ambiguous; higher domestic emissions E_H^0 increase the likelihood that a tariff hike will raise emissions.

See Appendix A.1 for proofs and special cases.

2.2 Provision of a subsidy to production in the home country

In this subsection, we consider the provision of a subsidy to production in the home country. This changes our supply functions. We now have:

$$S_F = S_F^0 \left(1 + \eta_F \frac{P_F - P_F^0}{P_F^0}\right),$$

and, with the subsidy s,

$$S_H = S_H^0 \left(1 + \eta_H \frac{P_H + s - P_H^0}{P_H^0}\right).$$

For simplicity, we assume $P_H = P_F = P$.

Providing a subsidy leads to the following price expression and derivative:

$$\frac{P}{P^0} = 1 + \frac{\eta_H}{\mu_H - \chi_F} \frac{s\, S_H^0}{P^0 X_F^0},$$

$$\frac{\partial P}{\partial s} = \frac{\eta_H}{\mu_H - \chi_F} \frac{S_H^0}{X_F^0} < 0.$$

This result indicates that introducing a subsidy for production in the home country will lower prices in both the home and foreign countries.

The total supply becomes:

$$S = S^0 + \eta_H \frac{s\, S_H^0}{P^0} \left[1 - \frac{\eta}{\chi_F - \mu_H} \frac{S^0}{X_F^0} \right],$$

and its derivative is

$$\frac{\partial S}{\partial s} = \frac{\eta_H S_H^0}{P^0} \left[1 - \frac{\eta}{\chi_F - \mu_H} \frac{S^0}{X_F^0} \right].$$

Given that $X_F^0(\chi_F - \mu_H) = \eta S^0 - \epsilon D^0$ and $\epsilon < 0$, we have

$$1 > \frac{\eta}{\chi_F - \mu_H} \frac{S^0}{X_F^0},$$

which implies that a subsidy on production will increase total production.

Assuming emissions are linearly related to supply, we obtain:

$$E = E^0 + \eta_H \frac{s}{P^0} \left[E_H^0 - \frac{\eta_H E_H^0 + \eta_F E_F^0}{\chi_F - \mu_H} \frac{S_H^0}{X_F^0} \right],$$

and therefore

$$\frac{\partial E}{\partial s} = \frac{\eta_H}{P^0} \left[E_H^0 - \frac{\eta_H E_H^0 + \eta_F E_F^0}{\chi_F - \mu_H} \frac{S_H^0}{X_F^0} \right].$$

In this case, the sign of the derivative is ambiguous; it depends on the relationship between $(\eta - \epsilon)E_H^0 S^0$ and $(\eta_H E_H^0 + \eta_F E_F^0)S_H^0$. If the former exceeds the latter, the subsidy will lead to increased emissions.

See Appendix A.2 for further details.

Chapter 3

Model

This section introduces the agricultural trade model in partial equilibrium used to analyze policy impacts on GHG emissions. The model is based on Gouel and Laborde (2021), with multilogit functions replacing the Fréchet yield functions originally employed, as described in Gouel et al. (202?). While the Fréchet approach assumes heterogeneous land quality, leading to yields following a Fréchet distribution with respect to specialization rates, the multilogit approach treats land as homogeneous. Instead, a management function—where costs vary with different levels of specialization—allows for the incorporation of heterogeneity.

3.1 Setups

Countries are indexed by i or $j \in \mathcal{J}$, goods by $k \in \mathcal{K}$, with $k = 0$ the non-agricultural goods acting as numeraire, $k = l$ the livestock products, $k = g$ grass, $k \in \mathcal{K}^c$ the crops ($\mathcal{K}^c \in \mathcal{K}$), and $k_p \in \mathcal{K}^p$ the non-crop products ($\mathcal{K}^p \subset \mathcal{K}$). We note $\mathcal{K}^a = \mathcal{K}^c \cup \mathcal{K}^p \cup l$ representing all the agricultural goods that can be exported, grace is not tradable, and is only use to feed livestock.

For more clarity in appendix B, a table mapping all variables and parameter is available.

3.2 Model in level

3.2.1 Consumption

Considering a demand for agricultural goods inelastic to income, we denote the total consumption for the bundle of agricultural products in country j, C_j, with:

$$C_j = \left[\sum_{k \in \mathcal{K}^a} (\beta_j^k)^{1/\kappa} (C_j^k)^{(\kappa-1)/\kappa} \right]^{\kappa/(\kappa-1)}, \tag{3.1}$$

$\kappa > 0$ is the elasticity of substitution between agricultural product, and is considered to be the same in every countries, C_j^k represents the consumption for product k, and β_j^k is an exogenous preference parameter.

3.2.2 Trade

3.2.3 Production

Crops

Processes

Animal products

Non-crop products

3.3 Model in relative change

We adapt all previous equations to a square system in calibrated change, with $\hat{x} = x'/x$, the relative change of variable x between its baseline equilibrium x, and the counterfactual one x'. Considering relative change instead of final level, allows us to avoid calibrating all parameters (e.g. our β will disappear), since the preferences are the same between the initial and the final situation, their parameters disappear when calibrating them the equations.

Chapter 4

Taking the model to the data

- tidy_faostat (récupération données, agrégation + nettoyage)

- tidy_fabio (agrégation, nettoyage des losses, et process)

- valeur arbitraire choisit en fonction des autres papiers ou de la plouf (du coup là plouf pour le share cost labor et land)

Chapter 5

Results

Chapter 6

Conclusion

Appendix A

Intuition

A.1 Tariff

First, we express P_F as a function of t and the elasticities.

Starting from the equation

$$D_H - S_H = S_F - D_F,$$

and using the definitions of demand and supply, we obtain:

$$D_H^0 \left(1 + \epsilon_H \frac{P_H - P_H^0}{P_H^0}\right) - S_H^0 \left(1 + \eta_H \frac{P_H - P_H^0}{P_H^0}\right) = S_F^0 \left(1 + \eta_F \frac{P_F - P_F^0}{P_F^0}\right) - D_F^0 \left(1 + \epsilon_F \frac{P_F - P_F^0}{P_F^0}\right).$$

We then factorize by $\frac{P_i - P_i^0}{P_i^0}$ for $i = H, F$:

$$\frac{P_H - P_H^0}{P_H^0}[D_H^0 \epsilon_H - S_H^0 \eta_H] + D_H^0 - S_H^0 = \frac{P_F - P_F^0}{P_F^0}[S_F^0 \eta_F - D_F^0 \epsilon_F] + S_F^0 - D_F^0.$$

Noting that $D_H^0 - S_H^0 = S_F^0 - D_F^0$, we obtain:

$$\frac{P_H - P_H^0}{P_H^0}[D_H^0 \epsilon_H - S_H^0 \eta_H] = \frac{P_F - P_F^0}{P_F^0}[S_F^0 \eta_F - D_F^0 \epsilon_F].$$

Using the aggregated elasticities defined in Chapter 2.1, we have

$$\frac{P_F}{P_F^0} = -\frac{\mu_H(1 - t/P_H^0) - \chi_F}{\eta - \epsilon} \frac{X_F^0}{D^0}.$$

Multiplying both sides by P_F^0, a straightforward derivation yields:

$$\frac{\partial P_F}{\partial t} = \frac{\mu_H}{\eta - \epsilon} \frac{X_F^0}{D^0} \frac{P_F^0}{P_H^0} < 0.$$

Assuming an initial tariff of zero, i.e. $P_F^0 = P_H^0$, we have:

$$\frac{P_F}{P_F^0} = -\frac{(1 - t/P_H^0)\mu_H - \chi_F}{\chi_F - \mu_H} = 1 + \frac{\mu_H}{\chi_F - \mu_H} \frac{t}{P_H^0}.$$

Assuming an initial tariff of zero and uniform elasticities across countries, the price and its derivative are given by:

$$P_F = P_F^0 + t \frac{\mu_H}{\eta_i - \epsilon_i} \frac{X_F^0}{D^0},$$

$$\frac{\partial P_F}{\partial t} = \frac{\mu_H}{\eta_i - \epsilon_i} \frac{X_F^0}{D^0} < 0.$$

Regarding total production Q, with an initial tariff of zero we have:

$$\begin{aligned} Q &= Q^0 + \frac{-\frac{t}{P_H^0}\eta_i(S_H^0\chi_F + S_F^0\mu_H)}{\mu_H - \chi_F}, \\ \frac{\partial Q}{\partial t} &= \eta_i \frac{S_H^0\chi_F + S_F^0\mu_H}{\chi_F - \mu_H}\frac{1}{P_H^0}. \end{aligned}$$

For emissions, using $E_i = e_i S_i$, we obtain the results presented in Section 2.1. In addition, assuming an initial tariff of zero and equal elasticities (i.e., $\eta_H = \eta_F = \eta_i$ and $\epsilon_H = \epsilon_F = \epsilon_i$), we have:

$$\begin{aligned} E &= E^0 + \frac{\frac{t}{P_H^0}\eta_i(E_H^0\chi_F + E_F^0\mu_H)}{\chi_F - \mu_H}, \\ \frac{\partial E}{\partial t} &= \eta_i \frac{E_H^0\chi_F + E_F^0\mu_H}{\chi_F - \mu_H}\frac{1}{P_H^0}. \end{aligned}$$

A.2 Subvention

By rewriting the equilibrium equation with the new supply functions,

$$D_H^0\left(1 + \epsilon_H\frac{P - P^0}{P^0}\right) - S_H^0\left(1 + \eta_H\frac{P + s - P^0}{P^0}\right) = S_F^0\left(1 + \eta_F\frac{P - P^0}{P^0}\right) - D_F^0\left(1 + \epsilon_F\frac{P - P^0}{P^0}\right),$$

we obtain the price and its derivative as presented in Section 2.2.

When elasticities are uniform across countries, so that $\epsilon_i = \epsilon$ and $\eta_i = \eta$, we have:

$$\begin{aligned} \frac{P}{P^0} &= 1 + \frac{\eta}{\mu_H - \chi_F}\frac{sS_H^0}{P^0 X_F^0}, \\ \frac{\partial P}{\partial s} &= -\frac{\eta}{\chi_F - \mu_H}\frac{S_H^0}{X_F^0} < 0. \end{aligned}$$

With regard to supply, we have:

$$S = S_F + S_H = S^0 + S^0\eta\frac{P - P^0}{P^0} + S_H\eta_H\frac{s}{P^0},$$

which yields the results in Section 2.2.

For emissions, using again $E = e_H S_H + e_F S_F$, in the case of uniform elasticities the introduction of the subsidy results in higher emissions only if

$$\frac{E_H^0}{\eta S_H^0} > \frac{E^0}{(\eta - \epsilon)S^0}.$$

Appendix B

Intuition

One can find here a list of the variables used in the model from chapter 3, for more clarity.

Name	Description	Type
$\beta_{ij}^k \geq 0$	preference for good k produced in country i and consumed in j (exogenous)	param
$\kappa > 0 \neq 1$	elasticity of substitution between agr product	param
$\kappa_{\text{feed}} > 0$	elasticity of substitution between various feed crops	param
$\sigma > 0 \neq 1$	Armington elasticity of substitution	param
$\epsilon > 0$	opposite of price elasticity of demand for the agricultural bundle	param
p_j^k and P_j^k	producer and composite price of imports of good k in country j	variables
$\tau_{ij}^k \geq 1$	iceberg cost from i to j for k, here $= 1$	param
C_j^0	final consumption of non-agr product, $P_j^0 = 1$	variable
C_j^k	final consumption of product k in j	variable
${x^\lambda}_j^k$	content of k in process λ or livestock feed in country j	variable
${\mu^\lambda}_i^k$	conversion ratio of k in process λ or of livestock feed	param
ν_i^k	unit of labor required per unit of land	param
$A_i^0 > 0$	labor productivity (in money), equal to wages $A_i^0 = w_i$	param
N_i^0	labor demand for no-agr good in country i	param
L_i^k	surface of field dedicated to k in country $i = s_i^k L_i$	variable
r_i^k and R_i^k	per hectare and total land rents ($R_i^k = r_i^k L_i^k$)	variables
s_i^k	share of field in country i allocated to k	variable
Q_i^k	total output of k in i ($Q_i^k = s_i^k L_i^k Y_i^k$)	variable
$Q_i^{l_\lambda}$	qtt of output l in the process λ	variable
$Q_i^\lambda = \sum Q_i^{l_\lambda}$	total qtt of output in the process λ	variable
${\upsilon^\lambda}_i^{l_\lambda} = Q_i^{l_\lambda}/Q_i^\lambda$	mass proportion of output l_λ in the process λ	parameter
${m^\lambda}_i^{k_\lambda} = {x^\lambda}_i^{k_\lambda}/x_i^\lambda$	mass proportion of input k_λ in process λ	parameter
y_i^k and Y_i^k	average and total yields of k in i	param, variable
$\varsigma_i^k > 0$	yield elasticity	param
X_i^k	quantity of inputs that intensify land	variables
P_i^X	price of X in country i	param
P_i^Z	price of non-land-intensifying input	param
$\alpha_i > 0$	behavioral parameter that governs the acreage elasticity	param
$X_{v,ij}^k$	volume of bilateral export between i and j for good k	variable
B_i	trade balance/deficits of country i	variable
E_i	expenditures	variable