Appendix D: Brain drain in Bhutan: its impacts and countermeasures

The model equations, variables, and parameters

Sets

i, j	sectors (primary, manufacturing, electricity, services, and public)
h	factors of production (skilled, unskilled labor, and capital)
lab	labor (skilled and unskilled labor)

Endogenous Variables

Y_j	composite factor
$F_{h,j}$	the h-th factor input by the j-th sector
	$F_{lab,j}$ and $F_{K,j}$ are labor and capital inputs by the j-th sector
$X_{i,j}$	intermediate input
Z_j	output of the j-th good
X_i^p	household consumption of the i-th good
X_i^g	government consumption of the i-th good
X_i^v	investment demand for the i-th good
E_i	exports
M_i	imports
Q_i	Armington's composite good
D_i	domestic good
S^p	private savings
S^g	government savings
T^d	direct tax
T_j^z	production tax
T_j^m	import tariff
Tr^g	government transfer to household
p_h^f	the h-th factor price
	p_{lab}^f and p_K^f are labor and capital prices
p_j^y	composite factor price
p_j^z	supply price of the i-th good
p_i^q	Armington's composite good price
p_i^e	export price in local currency
p_i^m	import price in local currency
p_i^d	the i-th domestic good price
ϵ	exchange rate
TF_{lab}	total employed workforce
DF_{lab}	labor employed in the domestic market
RF_{lab}	labor employed in the foreign market
LR_{lab}	Leisure
R^m	Remittances
CC	composite consumption of goods
UU	utility
p_{lab}^{tf}	composite labor wages
p_{lab}^{df}	labor wage rate in the domestic market
p^{cc}	composite goods price

Exogenous Variables

τ^d	direct tax rate
τ_i^z	production tax rate
τ_i^m	import tariff rate
τ^g	government transfer rate
ss^p	average propensity for private savings
ss^g	average propensity for government savings
p_i^{We}	export price in US dollars
p_i^{Wm}	import price in US dollars
FF_h	factor endowment of the h-th factor
S^f	foreign savings in US dollars
LF_{lab}	total labor force
p_{lab}^{rf}	foreign labor wage rate
CPI	consumer price index

Parameters

$ax_{i,j}$	intermediate input requirement coefficient
ay_j	composite factor input requirement coefficient
mu_i	government consumption share
λ_i	investment demand share
δ_i^m	share parameter in Armington function
δ_i^d	share parameter in Armington function
γ_i	scale parameter in Armington function
ξ_i^d	share parameter in transformation function
ξ_i^e	share parameter in transformation function
θ_i	scale parameter in transformation function
η_i	substitution elasticity parameter
ϕ_i	transformation elasticity parameter
$\beta_{h,j}$	factor share parameter in production function
b_j	scale parameter in production function
α_i	share parameter in composite consumption
a	scale parameter in composite consumption
$\alpha 1$	share parameter in utility function
$\alpha 2_{lab}$	share parameter in utility function
B_{lab}^{tf}	scale parameter in labor transformation function
δ_{lab}^{rf}	share parameter in labor transformation function
δ_{lab}^{df}	share parameter in labor transformation function
κ_{lab}	labor transformation elasticity parameter
ρ^u	substitution elasticity parameter in utility

Model Equations

Domestic production behavior

$$Y_j = b_j \prod_h F_h^{\beta_{h,j}} \tag{1}$$

$$F_{h,j} = \frac{\beta_{h,j} p_j^y}{p_{h,j}^f} Y_j \tag{2}$$

$$X_{i,j} = ax_{i,j} Z_j \tag{3}$$

$$Y_j = ay_j Z_j \tag{4}$$

$$p_j^z = ay_j p_j^y + \sum_i ax_{i,j} p_i^q \tag{5}$$

Government behavior

$$T^d = \tau^d \left(\sum_{lab,j} p_{lab,j}^f F_{lab,j} + \sum_j p_{K,j}^f F_{K,j} \right) \tag{6}$$

$$T_j^z = \tau_j^z \left(p_j^z Z_j \right) \tag{7}$$

$$T_i^m = \tau_i^m \left(p_i^m M_i \right) \tag{8}$$

$$Tr^g = \tau^g \left(T^d + \sum_j T_j^z + \sum_j T_j^m \right) \tag{9}$$

$$X_i^g = \frac{\mu_i}{p_i^q} \left(T^d + \sum_j T_j^z + \sum_j T_j^m - S^g - Tr^g \right) \tag{10}$$

Investment and savings

$$X_i^v = \frac{\lambda_i}{p_i^q} \left(S^p + S^g + \epsilon S^f \right) \tag{11}$$

$$S^p = ss^p \left(\sum_{lab,j} p_{lab,j}^f F_{lab,j} + \sum_j p_{K,j}^f F_{K,j} + Tr^g + \epsilon R^m - T^d \right) \tag{12}$$

$$S^g = ss^g \left(T^d + \sum_j T_j^z + \sum_j T_j^m \right) \tag{13}$$

Household behavior

$$X_i^p = \frac{\alpha_i}{p_i^q} \left(p^{cc} CC \right) \tag{14}$$

$$CC = a \prod_i X_i^{p\alpha_i} \tag{15}$$

$$CC = \frac{\alpha 1}{p^{cc}} \left(\frac{\text{factor income} + Tr^g - T^d - S^p}{\alpha 1^v p^{cc\,1-v} + \sum_{lab} \alpha 2_{lab}^v p_{lab}^{tf\;1-v}} \right) \tag{16}$$

$$LR_{lab} = \frac{\alpha 2_{lab}}{p_{lab}^{tf}} \left(\frac{\text{factor income} + Tr^g - T^d - S^p}{\alpha 1^v p^{cc\,1-v} + \sum_{lab} \alpha 2_{lab}^v p_{lab}^{tf\;1-v}} \right) \tag{17}$$

$$\text{factor income} = \sum_{h,j} p_{h,j}^{tf} F_{h,j} + \sum_{lab} p_{lab}^{tf} LR_{lab} + \epsilon R^m \tag{18}$$

Export and import prices and the balance of payments constraint

$$p_i^e = \epsilon p_i^{We} \tag{19}$$

$$p_i^m = \epsilon p_i^{Wm} \tag{20}$$

$$\sum_i p_i^{We} E_i + S^f + R^m = \sum_i p_i^{Wm} M_i \tag{21}$$

Transformation between exports and domestic goods

$$Z_i = \theta_i \left(\xi e_i E_i^{\phi_i} + \xi d_i D_i^{\phi_i} \right)^{\frac{1}{\phi_i}} \tag{22}$$

$$E_i = \left(\frac{p_i^z \theta_i^{\phi_i} \xi e_i}{p_i^e} \right)^{\frac{1}{1-\phi_i}} Z_i \tag{23}$$

$$D_i = \left(\frac{p_i^z \theta_i^{\phi_i} \xi d_i}{p_i^d} \right)^{\frac{1}{1-\phi_i}} Z_i \tag{24}$$

Substitution between imports and domestic goods (Armington composite)

$$Q_i = \gamma_i \left(\delta m_i M_i^{\eta_i} + \delta d_i D_i^{\eta_i} \right)^{\frac{1}{\eta_i}} \tag{25}$$

$$M_i = \left(\frac{p_i^q \gamma_i^{\eta_i} \delta m_i}{p_i^q} \right)^{\frac{1}{1-\eta_i}} Q_i \tag{26}$$

$$D_i = \left(\frac{p_i^q \gamma_i^{\eta_i} \delta d_i}{p_i^q} \right)^{\frac{1}{1-\eta_i}} Q_i \tag{27}$$

Labor transformation between domestic and foreign employment

$$TF_{lab} = B_{lab}^{tf} \left(\delta_{lab}^{rf} RF_{lab}^{\kappa_{lab}} + \delta_{lab}^{df} DF_{lab}^{\kappa_{lab}} \right)^{\frac{1}{\kappa_{lab}}} \tag{28}$$

$$DF_{lab} = \left(\frac{B_{lab}^{tf\ \kappa_{lab}} \delta_{lab}^{df} p_{lab}^{tf}}{p_{lab}^{df}} \right)^{\frac{1}{1-\kappa_{lab}}} TF_{lab} \tag{29}$$

$$RF_{lab} = \left(\frac{B_{lab}^{tf\ \kappa_{lab}} \delta_{lab}^{rf} p_{lab}^{tf}}{\epsilon p_{lab}^{rf}} \right)^{\frac{1}{1-\kappa_{lab}}} TF_{lab} \tag{30}$$

$$R^m = \sum_{lab} p_{lab}^{rf} RF_{lab} \tag{31}$$

Market clearing conditions

$$Q_i = X_i^p + X_i^g + X_i^v + \sum_j X_{i,j} \tag{32}$$

$$LF_{lab} = TF_{lab} + LR_{lab} \tag{33}$$

$$\sum_j F_{lab,j} = FF_{lab} \tag{34}$$

$$K_j = K0_j \tag{35}$$

$$p_{lab,i}^f = p_{lab,j}^f \tag{36}$$

Utility

$$UU = \left(\alpha 1 CC^{\rho^u} + \sum_{lab} \alpha 2_{lab} LR_{lab}^{\rho^u} \right)^{\frac{1}{\rho^u}} \tag{37}$$

Consumer Price Index

$$CPI = \sum_j \left(\frac{p_j^q X_j^{p0}}{X_j^{p0}} \right) \tag{38}$$