Online appendices for: "The new Northern Ireland protocol: Can Northern Ireland enjoy the best of both worlds?"

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A: NICGE Core Model Equations

Production Technology	
CES production $Y_{JT} = C_J^{Y\,\sigma_J^Z} \left[\frac{P_{JT}^X}{P_{JT}^Y}\right]^{\sigma_J^Z} X_{JT}$ **(A1)**	Y_{JT} – value added P_{JT}^Y – value added price C_J^Y – calibrated coefficient for unit of output X_{JT} – gross output P_{JT}^X – gross output price
$VV_{IJT} = C_{IJ}^{V\,\sigma_I^Z} \left[\frac{P_{IT}^X}{P_{IT}^Q}\right]^{\sigma_I^Z} X_{JT}$ **(A2)**	VV_{IJT} – intermediate inputs P_{IT}^Q – composite price C_{IJ}^V – calibrated coefficient for intermediate inputs I and J (Leontief)
$Y_{JT} = \left[\alpha_J \left(EK_{JT} KD_{JT}\right)^{\rho_J^Y} + \beta_J \left(EL_{JT} LD_{JT}\right)^{\rho_J^Y}\right]^{\frac{1}{\rho_J^Y}}$ **(A3)**	EL_{JT} – labour augmenting technology EK_{JT} – capital augmenting technology
$LD_{JT} = \left[EL_{JT}{}^{\rho_J^Y} \beta_J \frac{P_{JT}^Y}{WF_T}\right]^{\frac{1}{1-\rho_J^Y}} Y_{JT}$ **(A4)**	LD_{JT} – labour demand WF_T – firms' labour costs before tax
$RK_{JT} = P_{JT}^Y \alpha_J EK_{JT}{}^{\rho_J^Y} \left[\frac{Y_{JT}}{KD_{JT}}\right]^{1-\rho_J^Y}$ **(A5)**	KD_{JT} – capital demand RK_{JT} – rate of return on capital α_J – calibrated CES parameter for capital

	β_J – calibrated CES parameter for labour σ_J^Z – elasticity between value added and intermediate ρ_J^Y – substitution parameter for factors
Taxes on Production, Import and Production Subsidies	
$IBT_{IT} = BTAX_I X_{IT} P_{IT}^X$ **(A6)** $IMT_{JT} = \sum_I VM_{IJT} MTAX_J P_{JT}^M$ **(A7)** $SUBSY_{IT} = SUB_I X_{IT} P_{IT}^X$ **(A8)**	IBT_{IT} – indirect business tax $BTAX_I$ – indirect business tax rate X_{IT} – gross output P_{IT}^X – gross output price IMT_{JT} – indirect import tax $\sum_I VM_{IJT}$ – imported intermediate input from ROW $MTAX_J$ – import tax rate P_{JT}^M – import price $SUBSY_{IT}$ – production subsidy SUB_I – subsidy rate X_{IT} – gross output P_{IT}^X – gross output price
Intermediate Demand	
$VV_{IJT} = \left(\delta_{IJ}^{VM}\left(\gamma_{IJ}^{VM} VM_{IJT}\right)^{\rho_I^V} + \delta_{IJ}^{VIR}\left(\gamma_{IJ}^{VIR} VIR_{IJT}\right)^{\rho_I^V}\right)^{\frac{1}{\rho_I^V}}$ **(A9)** $VM_{IJT} = VIR_{IJT}\left[\frac{\delta_{IJ}^{VM}}{\delta_{IJ}^{VIR}} \frac{\gamma_{IJ}^{VM}}{\gamma_{IJ}^{VIR}} \frac{P_{IT}^{IR}}{P_{IT}^M}\right]^{\frac{1}{1-\rho_I^V}}$ **(A10)**	VV_{IJT} – intermediate inputs $\gamma_{IJ}^{VM}, \gamma_{IJ}^{VIR}$ – shift parameters in Armington $\gamma_{IJ}^{TR}, \gamma_{IJ}^{TI}$ – shift parameters in Armington δ_{IJ}^{VM}, δ_{IJ}^{VIR} – share parameters VM_{IJT} – ROW input VI_{IJT} – RUK input VIR_{IJT} – intermediate input (RUK + domestic)

$VIR_{IJT} = \left(\delta_{IJ}^{VI}\left(\gamma_{IJ}^{TI}VI_{IJT}\right)^{\rho_I^V} + \delta_{IJ}^{VR}\left(\gamma_{IJ}^{TR}VR_{IJT}\right)^{\rho_I^V}\right)^{\frac{1}{\rho_I^V}}$ **(A11)** $VR_{IJT} = VI_{IJT}\left[\frac{\delta_{IJ}^{VR}}{\delta_{IJ}^{VI}}\frac{\gamma_{IJ}^{TR}}{\gamma_{IJ}^{TI}}\frac{P_{0I}^{I}}{P_{IT}^{R}}\right]^{\frac{1}{1-\rho_I^V}}$ **(A12)** $TV_{JT} = \sum_I VV_{IJT}$ **(A13)** $TVR_{JT} = \sum_I VR_{IJT}$ **(A14)** $TVI_{JT} = \sum_I VI_{IJT}$ **(A15)** $TVM_{JT} = \sum_I VM_{IJT}$ **(A16)**	P_{IT}^{IR} – price of RUK + domestic composite good P_{IT}^{M} – import price ρ_I^V – substitution parameter δ_{IJ}^{VR}, δ_{IJ}^{VI} – share parameter P_{0I}^{I} – RUK price P_{IT}^{R} – domestic good price TV_{JT} – total intermediate inputs TVR_{JT} – total regional intermediate input TVI_{JT} – total imported intermediate from RUK TVM_{JT} – total imported intermediate goods from ROW
Goods market balance	
$X_{IT} + M_{IT} = \sum_J VV_{IJT} + Q_{IT}^{H} + E_{IT}$ $+Q_{IT}^{V} + Q_{IT}^{G} + TUTOT_{IT} + STOCKTOT_I$ **(A17)**	X_{IT} – gross output E_{IT} – exports M_{IT} – imports $\sum_J VV_{IJT}$ – total intermediate imports in sector i Q_{IT}^{H} – household consumption Q_{IT}^{V} – investment demand Q_{IT}^{G} – government consumption $TUTOT_{IT}$ – tourism consumption $STOCKTOT_I$ – total stock
Exports	

$X_{IT} = R_{IT} + E_{IT}$ **(A18)**	X_{IT} – gross output E_{IT} – exports R_{IT} – domestic goods
$E_{IT} = E_{IT}^{REG} + E_{IT}^{INT}$ **(A19)**	E_{IT}^{REG} – exports to RUK E_{IT}^{INT} – exports to ROW
$E_{IT}^{REG} = SIMRUK_{IT} E_{0I}^{REG} \left(\frac{P_{IT}^{E}}{P_{IT}^{Q}}\right)^{\sigma_I^X}$ **(A20)**	$SIMRUK_{IT}$, $SIMROW_{IT}$ – simulation variables E_{0I}^{INT} – exports to ROW in base year E_{0I}^{REG} – exports to RUK in base year σ_I^X – export elasticity
$E_{IT}^{INT} = SIMROW_{IT} E_{0I}^{INT} \left(\frac{P_{IT}^{E}}{P_{IT}^{Q}}\right)^{\sigma_I^X}$ **(A21)**	P_{IT}^{Q} – commodities price P_{IT}^{E} – export price
$R_{IT} = \sum_J VR_{IJT} + Q_{IT}^{HR} + Q_{IT}^{VR}$ $+ Q_{IT}^{GR} + TURREG_{IT} + STOCKREG_I$ **(A22)**	$\sum_J VR_{IJT}$ – total regional intermediate input in sector j $TURREG_{IT}$ – Tourists regional consumption $STOCKREG_I$ – Regional stock
Income and Output	
$LY_T = \sum_J LD_{JT} WF_T$ **(A23)**	LY_T – labour income $\sum_J LD_{JT}$ – total labour demand WF_T – firms' labour costs before tax
$KY_T = \sum_J KD_{JT} RK_{JT}$ **(A24)**	KY_T – capital income $\sum_J KD_{JT}$ – total capital demand RK_{JT} – rate of return on capital
$GRP_T = C_T + \sum_I Q_{IT}^{G} + \sum_I Q_{IT}^{V}$ $+ \sum_I TUTOT_{IT} + \sum_I E_{IT} - \sum_I M_{IT}$ **(A25)**	GRP_T – gross domestic product C_T – household consumption $\sum_I Q_{IT}^{G}$ – total government consumption $\sum_I Q_{IT}^{V}$ – total investment $\sum_I TUTOT_{IT}$ – total stock $\sum_I E_{IT}$ – total exports $\sum_I M_{IT}$ – total imports
$TRSNG_{DNGINS,DNGINS,T}$ $= TRSNG_{0,DNGINS,DNGINSP} CPI_T$ **(A26)**	YNG^{H} – household income $NIEMPL_T$ – Employers' NICs CPI_T – consumer price index

$YNG_T^H = LY_T - NIEMPL_T + DSHR_{HH}KY_T + TRSNG_{HH,Firms,T} + SAM_{HH,Gov}CPI_T \sum_{FINS} SAM_{HH,FINS} * \varepsilon_T$ **(A27)** $YNG_T^F = DSHR_{Firms}KY_T + TRSNG_{Firms,HH,T} + SAM_{Firms,Gov}CPI_T + NIEMPL_T + \sum_{FINS} SAM_{Firms,FINS}\varepsilon_T$ **(A28)**	ε_T – exchange rate YNG^F – firms' income *TRSNG* – transfers *DSHR* – share of capital income *SAM* – values as given in the Northern Irish SAM *FINS* – foreign institutions
Household Taxes and Savings	
$SAV_T = (YNG_T^H - HTAX_T)MPSAV$ **(A29)** $HTAX_T = (LABTAX_{R_{NIHH}} + LABTAX_{R_{IT}} + LABTAX_{R_{OTH}}) * WHG_T \sum_I LD_{IT}$ **(A30)** $NIEMPL_T = LABTAX\_R_{NIF} * WHG_T \sum_I LD_{IT}$ **(A31)**	SAV_T – household saving $MPSAV$ – household savings rate: $\frac{SAV_0}{\sum_H TOT_H}$ YNG^H – household income $HTAX_T$ – household tax paid $LABTAX_R$ – effective labour tax rate by type: *NIHH* – employees' National insurance contributions *IT* – income tax *OTH* – other household taxes *NIF* – employers' National insurance contributions $NIEMPL_T$ – total payments of employers' NICs WHG_T – household gross wage LD_{IT} – firms' labour demand
Firm Taxes	
$ETAX_T = DTRE(YNG_T^F - NIEMPL_T)$ **(A32)** $CTAX_{IT} = RK_{IT}KS_{IT}TKT_{IT}$	$ETAX_T$ – firm taxes (excluding corporation tax) YNG^F – firms' income *NIEMPL* – firms' total expenditure on NICs

(A33) $CTAXTOT_T = \sum_I CTAX_{IT}$ **(A34)**	$DTRE$ – effective firm tax rate (excluding CT) $CTAX_{IT}$ – corporation tax revenues by sector RK_{IT} – interest rate KS_{IT} – capital supply TKT_{IT} – effective corporation tax rate $CTAXTOT_T$ – total corporation tax revenue
Foreign Debt	
$DEBT_T = (1 + IR - GINT_0)DEBT_{T-1} + BALPAY_{T-1}$ **(A35)** In first period only: $DEBT_T = DEBT_0$ **(A36)** In final period only: $-(IR - GINT_0)DEBT_T = BALPAY_T$ **(A37)**	$DEBT_T$ – foreign debt IR – interest rate $GINT_0$ – variable in CALIB model $DEBT_0$ – base year debt $BALPAY_T$ – balance of payments
Prices, Wages and Balance of Payments	
$P_{IT}^M = \varepsilon_T P_I^{WM}(1 + MTAX_I)$ **(A38)** $P_{JT}^Y = \begin{bmatrix} P_{JT}^R(1 - BTAX_J - SUB_J) \\ -\sum_I P_{JT}^Q CV_{IJ}{}^{\sigma_J^Z} - P_{JT}^M CMT_J \end{bmatrix} \frac{1}{CY_J{}^{\sigma_J^Z}}$ **(A39)** $UCK_T = P_T^{INV}(IR + \delta)$ **(A40)**	P_{IT}^M – import price P_I^{WM} – world import price $MTAX_I$ – import tax rate ε_T – exchange rate P_{JT}^Y – value added price CY_J – calibrated coefficient for a unit of output σ_J^Z – elasticity of substitution between value added and composite good

$$P_T^{CON} = \frac{\sum_I P_{IT}^Q Q_{0I}^H}{\sum_I P_{0I}^Q Q_{0I}^H}$$

(A41)

$$CPI_T = \frac{\sum_I P_{IT}^Q Q_{0I}^H}{\sum_I Q_{0I}^H}$$

(A42)

$$WHG_T = \frac{WHN_T}{(1 - (LABTAX\_R_{NIHH} + LABTAX\_R_{IT} + LABTAX\_R_{OTH}))}$$

(A43)

$$WF_T = WHG_T(1 + LABTAX\_R_{NIF})$$

(A44)

$$P_{IT}^E = \varepsilon_T P_I^{WE}(1 - TE_I)$$

(A45)

$$P_{IT}^X = \frac{P_{IT}^R R_{IT} + E_{IT} P_{IT}^E}{R_{IT} + E_{IT}}$$

(A46)

$$P_{JT}^Q = \frac{R_{JT} P_{JT}^R + P_{JT}^M M_{JT}}{R_{JT} + M_{JT}}$$

(A47)

$$P_{JT}^{IR} = \frac{R_{JT} P_{JT}^R + P_{0J}^I MVI_{JT}}{MVI_{JT} + R_{JT}}$$

(A48)

$$BALPAY_T = \sum_I M_{IT} + SAM_{ROW,Firms} + SAM_{RUK,Firms} + SAM_{RUK,Gov} + SAM_{ROW,Gov} - \left(\sum_{FINS} SAM_{Tur,FINS} + \sum_I E_{IT} \right.$$

P_{JT}^R – regional output price

P_{JT}^Q – composite good price

CV_{IJ} – calibrated coefficient for intermediate inputs

CMT_J – share of import tariffs of total production

$BTAX_J$ – indirect business tax rate

SUB_J – subsidy rate

UCK_T – user cost of capital

P_T^{INV} – price of investment good

IR – interest rate

δ – depreciation rate

P_T^{CON} – household consumption price

Q_{IH}^{0H} – household consumption

WHG_T – household gross wage

WHN_T – household net wage

LABTAX_R – effective direct labour tax rates by type

P_{IT}^E – export price

P_I^{WE} – world export price

TE_I – export tax rate (=0)

P_{IT}^X – gross output price

P_{IT}^R – regional good price

R_{IT} – regional good

E_{IT} – export

P_{IT}^E – price of export

P_{JT}^{IR} – regional and RUK price

P_{0J}^I – RUK price

MVI_{JT} – total imports from RUK

$BALPAY_T$ – balance of payments

$\sum_I M_{IT}$ – total imports

SAM – values as given in the Northern Irish SAM

FINS – foreign institutions

$+\sum_{FINS} SAM_{Gov,FINS}\varepsilon_T + \sum_{DNGINS,FINS} SAM_{DNGINS,FINS}\varepsilon_T\Big)$ **(A49)**	*DNGINS* – domestic non-government institutions
Household Consumption	
$U = \sum_{t=0}^{\infty}\left(\frac{1}{1+\rho}\right)^t \frac{{C_T}^{1-\sigma}-1}{1-\sigma}$ **(A50)**	ρ – rate of time preference r – interest rate σ – Constant elasticity of marginal utility
$\frac{C_T}{C_{T+1}} = \left[\frac{P_T^{CON}(1+\rho)}{P_{T+1}^{CON}(1+r)}\right]^{-\left(\frac{1}{\sigma}\right)}$ **(A51)**	Q_{IT}^H – household consumption by sector $HDEL_I$ – consumption share P_T^{CON} – consumption price P_{IT}^Q – composite price
$Q_{IT}^H = HDEL_I\left[\frac{P_T^{CON}}{P_{IT}^Q}\right]^{SIGINV} C_T$ **(A52)**	$SIGINV$ – elasticity of substitution (0.3) C_T – total household consumption γ_I^{QH} – shift parameter
$Q_{IT}^H = \gamma_I^{QH}\left[\delta_I^{QHIR} Q_{IT}^{HIR\rho_I^H} + \delta_I^{QHM} Q_{IT}^{HM\rho_I^H}\right]^{\frac{1}{\rho_I^H}}$ **(A53)**	δ_I^{QHIR},δ_I^{QHM}, δ_I^{QHI}, δ_I^{QHR} – share parameters Q_{IT}^{HIR} – domestic + RUK consumption Q_{IT}^{HM} – household consumption of imports
$Q_{IT}^{HIR} = Q_{IT}^{HM}\left[\frac{\delta_I^{QHIR}}{\delta_I^{QHM}}\frac{P_{IT}^M}{P_{IT}^{IR}}\right]^{\frac{1}{1-\rho_I^H}}$ **(A54)**	ρ_I^H – elasticity γ_I^{HT} - shift parameters
$Q_{IT}^{HIR} = \gamma_I^{HT}\left[\delta_I^{QHI} Q_{IT}^{HI\rho_I^H} + \delta_I^{QHR} Q_{IT}^{HR\rho_I^H}\right]^{\frac{1}{\rho_I^H}}$ **(A55)**	Q_{IT}^{HI} – RUK household consumption Q_{IT}^{HR} – domestic household consumption P_I^{I0} – RUK good price (base year)=1

$Q_{IT}^{HR} = Q_{IT}^{HI}\left[\frac{\delta_I^{QHR}}{\delta_I^{QHI}}\frac{P_I^{I0}}{P_{IT}^R}\right]^{\frac{1}{1-\rho_I^H}}$ **(A56)**	P_{IT}^R – regional good price
Government Expenditure and Revenues	
$GY_T = DSHR_{GOV}KY_T + \sum_I IBT_{IT} + \sum_I IMT_{IT} + HTAX_T + ETAX_T + CTAXTOT_T + \sum_I SUBSY_{IT}$ **(A57)** $GOVBAL_T = \left(GEXP_T P_T^{Gov} + SAM_{Firms,Gov}CPI_T + TRH_T CPI_T + SAM_{KFOR,Gov} + SAM_{RUK,Gov} + SAM_{ROW,Gov}\right) - \left(DSHR_{GOV}KY_T + \sum_I IBT_{IT} + \sum_I IMT_{IT} + HTAX_T + ETAX_T + CTAXTOT_T + \sum_I SUBSY_{IT}\right)$ **(A58)** $P_T^{GOV}BF_T = \left[1 + IR - DIN + \left(\frac{CPI_T}{CPI_{T-1}} - 1\right)\right]P_{T-1}^{GOV}BF_{T-1} + GOVBAL_{T-1}$ **(A59)** <u>In first period only:</u> $BF_T = BF_0$ **(A60)** <u>In final period only:</u> $-(IR - DIN)BF_T = GOVBAL_T$ **(A61)** $Q_{IT}^G = GDEL_I GEXP_T$ **(A62)**	GY_T – government income $DSHR_{GOV}$ – capital share of government KY_T – capital income $\sum_I IBT_{IT}$ – indirect business tax revenues $\sum_I IMT_{IT}$ – import tax revenues (= 0) $HTAX_T$ – household tax revenues $ETAX_T$ – firm tax revenues (excl. CT) $CTAXTOT_T$ – CT revenues $\sum_I SUBSY_{IT}$ – subsidies $GOVBAL_T$ – government deficit *SAM* – values as given in the Northern Irish SAM *GEXP* – current government spending P_T^{GOV} – government price index *TRH* – transfers to households BF_T – gov. borrowing IR – interest rate DIN – calibrated variable Q_{IT}^G – government consumption $GDEL_I$ – consumption share Q_{IT}^{GM}- imports by government (= 0)

$Q_{IT}^{GM} = Q_{0I}^{GM}$ **(A63)** $Q_{IT}^{GR} = Q_{0I}^{G} - Q_{0I}^{GM}$ **(A64)** $P_T^{GOV} = \frac{\sum_I P_{IT}^Q Q_{0I}^G}{\sum_I P_{0I}^Q Q_{0I}^G}$ **(A65)**	P_{IT}^Q – composite price *TKT*, *TK* – effective corporation tax rate RK_{0I} –return on capital KS_{0I} – capital supply
Investment "Demand" (investment by sector of origin)	
$Q_{IT}^V = \sum_J KMATRIX_{IJ} JINV_{JT}$ **(A66)** $Q_{IT}^V = \gamma_I^{QV}\left[\delta_I^{QM}(Q_{IT}^{VM})^{\rho_I^v} + \delta_I^{QVIR}(Q_{IT}^{VIR})^{\rho_I^V}\right]^{\frac{1}{\rho_I^V}}$ **(A67)** $Q_{IT}^{VM} = Q_{IT}^{VIR}\left[\frac{\delta_I^{QM}}{\delta_I^{QVIR}}\frac{P_{IT}^{IR}}{P_{IT}^{M}}\right]^{\frac{1}{1-\rho_I^V}}$ **(A68)** $Q_{IT}^{VIR} = \gamma_I^{QT}\left[\delta_I^{QVI}\left(Q_{IT}^{VI}\right)^{\rho_I^V} + \delta_I^{QVR}\left(Q_{IT}^{VR}\right)^{\rho_I^V}\right]^{\frac{1}{\rho_I^V}}$ **(A69)** $Q_{IT}^{VR} = Q_{IT}^{VI}\left(\frac{\delta_I^{QVR}}{\delta_I^{QVI}}\frac{P_{0I}^I}{P_{IT}^X}\right)^{\frac{1}{1-\rho_I^V}}$ **(A70)**	Q_{IT}^V – investment demand by sector *KMATRIX* – parameter linking investment by destination and origin *JINV* – Investment by destination (incl. adjustment costs and tax credits) γ_I^{QV} - shift parameter δ_I^{QM} δ_I^{QVIR} – share parameters Q_{IT}^{VM} – imported investment Q_{IT}^{VIR} – investment (RUK and domestic) P_{IT}^{IR} – domestic + RUK price P_{IT}^M – export price γ_I^{QI} – shift parameter in Armington Q_{IT}^{VI} – investment RUK Q_{IT}^{VR} – domestic investment P_{0I}^I – RUK price P_{IT}^X – gross output price γ_J^{QT} – shift parameter in HH CES δ_I^{QVI} – share parameter
Investment and Capital Accumulation	

$KST_{JT} = \left(\frac{EK_{JT}^{\rho_J^Y} \alpha_J P_{JT}^Y}{UCK_T} \right)^{\frac{1}{1-\rho_J^Y}} Y_{JT}$ **(A71)** $JINV_{IT} = IND_{IT}(1 - BOP_{0I} + COP_{0I} - TAXC_I + \frac{ADJ}{2}\frac{IND_{IT}^2}{KS_{IT}})$ **(A72)** $PINV_T = \frac{\sum_{IJ} PQ_{JT}(1-TKT_{IT})^{-1} KMATRIX_{IJ}}{\sum_{IJ} PQ_{J0}(1-TK_I)^{-1} KMATRIX_{IJ}}$ **(A73)**	IND_{IT} - (net) investment KS_{IT} – capital supply δ – depreciation KST_{IT} – desired level of capital stock *SPEED* – speed of adjustment *JINV* – investment by destination (incl. adjustment costs and tax credits) BOP_{0I} – calibrated parameter (rate of distortion or incentive to invest) COP_{0I} – calibrated parameter (no economic meaning) $TAXC_I$ – rate of tax credit to investment *ADJ* – cost parameter PQ_{JT} – composite price *KMATRIX* – parameter linking investment by destination and origin $PINV_I$ – price of investment TKT_{IT} – effective CT rate EK_{IT} – capital augmenting technical change α_J – CES parameter for capital ρ_J^Y – elasticity of substitution between labour and capital P_{JT}^Y – value added price UCK_T – user cost of capital Y_{JT} – value added
Labour Market Closures	
<u>Regional Bargaining (REGBARG):</u> $ln\frac{WHN_T}{CPI_T} = AWE - 0.113\, ln\, U\, N_T$ **(A74)**	WHN_T – household wage after tax CPI_T – price level

National Bargaining (NATBARG): $WHG_T = WHG_0$ **(A75)** **Real Wage Resistance (FIXRW):** $\frac{WHN_T}{CPI_T} = \frac{WHN_0}{CPI_0}$ **(A76)**	AWE – calibrated parameter (based on real wage and unemployment in base) UN_T – Northern Ireland unemployment rate WHG_T – gross household wage
Capital Market Equilibrium	
$KS_{IT} = KD_{IT}$ **(A77)** $KS_{IT} = KS_{I,T-1}(1-\delta) + IND_{I,T-1}$ **(A78)** In first period only: $KS_{IT} = KS_{0I}$ **(A79)** In final period only: $KS_{IT}\delta = IND_{IT}$ **(A80)**	KS_{IT} – capital supply KD_{IT} – capital demand δ – depreciation of physical capital $IND_{I(T-1)}$ – investment by sector of destination
Labour Supply	
$LS_T(1-UN_T) = \sum_J LD_{JT}$ **(A81)**	LS_T – labour supply LD_{JT} – labour demand UN_T – unemployment rate
Import Demand	
$MVI_{JT} = Q_{JT}^{VI} + Q_{JT}^{HI} + \sum_I VI_{IJT}$ **(A82)** $M_{IT} = \sum_J VI_{IJT} + \sum_J VM_{IJT} + Q_{IT}^{HM} + Q_{IT}^{HI} + Q_{IT}^{GM} + Q_{IT}^{VI} + Q_{IT}^{VM} + TURIMP_{IT} + STOCKIMP_I$	MVI_{JT} – import demand (RUK goods) Q_{IT}^{VI} – investment imported from RUK Q^{HI} – imports by households from RUK

(A83)	$\sum_I VI_{IJT}$ – intermediate input from RUK M_{IT} – total imports $\sum_J VM_{IJT}$ – intermediate input from ROW Q^{HM} – imports by households from ROW Q_{IT}^{GM} – government consumption of ROW imports Q_{IT}^{VM} – investment imported from ROW $TURIMP_{IT}$ – consumption of imports by tourists $STOCKIMP_I$ – imported stock

B: Additional explanations

B1: Northern Ireland's service trade with ROW

Since the 1 January 2021, the UK has regained sovereignty over its trade policy. As such, the UK has the right to renegotiate trade deals with countries outside the EU. Thus, since 23 June 2016, the UK has signed many new trade agreements with countries such as Chile, Morocco, Switzerland and South Africa and mutual recognition agreements with Australia, New Zealand and the United States (GOV.UK, 2019). These took effect on 1 January 2021. Although it has made new agreements, the UK no longer benefits from many trade agreements it had access to as an EU member before 1 January 2021 (GOV.UK, 2019). Whilst the UK's trade policy is diverging from the EU's in many respects, it also has the choice to keep participating in many other agreements it signed as an EU member. These agreements include the Government Procurement Agreement, the Trade Facilitation Agreement, the TRIPS amendment and many more (World Trade Organization, 2020).

Given the complexity of estimating tariffs and NTBs for service trade in NI based on the UK's evolving trade deals with countries outside the EU, it was decided to assume that NI's service trade with countries outside the EU remains unchanged. This means that all results recorded must be interpreted as estimates of the impact on the NI economy of the changes in tariffs and NTBs between NI, GB and the EU.

B2. Other important specification decisions

As NI's government receives a block grant from the UK government every year, it is assumed that government expenditure is exogenously fixed in real terms (HM Treasury, 2020). This assumption is made as NI has no direct control over the block grant. Changes in the block grant received are determined by the Barnett formula which takes into account the UK government department's budget, the level of devolution in the region and the population share within the region (Keep & Matthew, 2020). Through Brexit, the UK government's budget will likely change. This will affect the block grant received in NI and thus affect NI's GDP. As at the time of writing, it is hard to predict by how much and in which direction the UK government's budget will change, it is assumed that real government expenditure is fixed in real terms.

NI's labour market is assumed to have a downward sloping wage curve (Blanchflower & Oswald, 2005). This is empirically observed for regions and used in other studies such as Latorre & Yonezawa (2020).

Capital accumulation follows a standard law of motion with next period's capital being equal to the contemporaneous period's capital less capital depreciation plus investment in new capital (see equation A78).

Investment is modelled as in Lecca, *et al*. (2013, p.4).

Households save at a constant rate defined using the base year's saving rate for NI.

B3. Elasticity of substitution between capital and labour

In this paper, it was decided to combine US sector level elasticities of substitution between capital and labour (σ_Ks) with an aggregate σ_K for the UK (Young, 2013; Smith, 2008). This decision was made as production processes across sectors are very different. Thus, it was thought that finding sector specific estimates would improve the method and thus the accuracy of the results. As no reliable sector specific σ_Ks were found for the UK, US estimates were adjusted such that their weighted average equals the aggregate σ_K estimate found by Smith (2018). It was assumed that, although US σ_Ks may be different to UK ones, the relative magnitudes across sectors would be better proxies for the actual σ_Ks than using aggregate data for all sectors. Although this method helped extrapolate sector specific estimates, it was imperfect as there are differences in production processes across countries and some of the sectors could not be mapped accurately. This was as the NI data available in the IO Tables for NI was less disaggregated than the US data (NISRA, 2020b). Thus, for some sectors, averages had to be used instead of weighted averages to map the broader US data onto the 18 sectors in NICGE. To test the importance of this assumption to the overall results, some simulations were run using an σ_K equal to 0.4 in all sectors. The results found were almost identical with differences in key macroeconomic variables being extremely small. The differences were slightly larger for sectors, however since none of the key conclusions drawn were changed, this methodological choice had no implications on the overall arguments presented in the paper.

B4. Other parameters

The initial unemployment rate is set to 2.7%, the ILO unemployment rate in NI in 2019 (ONS, 2020b).

The interest rate and depreciation rate of physical capital are set to 4.0% and 15.0% respectively (FAI, 2019).

The household yearly time preference discount factor is set equal to the interest rate (FAI, 2019).

The unemployment elasticity of the wage curve is set to -0.1. This is in line with Blanchflower & Oswald's (2005) estimates.

C: Mapping

Table C1: Elasticity of substitution between Capital and Labour (σ_K) by sector, United States

ID	Description	σ_K	ID	Description	σ_K
a1	Agriculture	0.68	**a19**	Stone, Clay and Glass	0.46
a2	Metal Mining	0.64	**a20**	Primary metal	0.69
a3	Coal Mining	0.78	**a21**	Fabricated metal	0.68
a4	Oil & gas extraction	0.87	**a22**	Nonelectrical sector	0.82
a5	Non-metallic mining	0.63	**a23**	Electrical sector	0.65
a6	Construction	0.5	**a24**	Motor vehicles	0.49
a7	Food & kindred products	0.39	**a25**	Transportation equipment & ordnance	1.13
a8	Tobacco	0.85	**a26**	Instruments	0.73
a9	Textile mill products	1.09	**a27**	Miscellaneous manufacturing	0.74
a10	Apparel	1.08	**a28**	Transportation	0.6
a11	Lumber & Wood	0.82	**a29**	Communications	0.48
a12	Furniture & Fixtures	0.46	**a30**	Electrical utilities	1
a13	Paper & allied	0.43	**a31**	Gas utilities	0.58
a14	Printing, publishing & allied	0.5	**a32**	Trade	0.43
a15	Chemicals	0.52	**a33**	Finance, insurance & real estate	1
a16	Petroleum & coal products	0.73	**a34**	Services	0.69
a17	Rubber & miscellaneous products	0.39	**a35**	Government enterprises	0.39
a18	Leather	1.41			

Source: *Young (2013)*

Description: Non-normalised GMM estimate of the sector specific elasticity of substitution between capital and labour for the United States (Young, 2013). The estimates are computed using 1960-2005 data from the KLEM database. ID stands for identifier.

Use: Mapped onto the NICGE sector classifications and normalised such that the aggregate elasticity of substitution between capital and labour in Northern Ireland equals the aggregate United Kingdom number estimated by the Bank of England (Smith, 2008).

Table C2: Armington elasticity of substitution by sector, United Kingdom

Identifier	Description	σ_A^{UKROW}
b1	Food products	1.92
b2	Alcohol & soft drinks	1.87
b3	Tobacco	-
b4	Textiles manufacturing	1.61
b5	Apparel manufacturing	1.60
b6	Leather & footwear manufacturing	1.40
b7	Wood	1.82
b8	Paper	1.57
b9	Chemical manufacturing	1.48
b10	Rubber & plastic	1.37
b11	Glass, stone & miscellaneous material	1.23
b12	Primary metals	1.58
b13	Metal products	1.25
b14	Electronic components	2.75
b15	Electronic motors	1.54
b16	Machinery manufacturing	1.32
b17	Motor vehicle components	2.09
b18	Transportation systems	1.15
b19	Toys, sports & leisure tools	2.65

Source: *Aspalter (2016)*

Description: 2-step GMM estimate of the Armington elasticity of substitution in the United Kingdom (Aspalter, 2016). 1995-2012 data from EUROSTAT's COMEXT database is used by Aspalter (2016).

Use: Mapped onto the NICGE sector classifications. These were then used to improve estimates of the Armington elasticity of substitution available from the GTAP Tables for 6 manufacturing sectors in NICGE.

Table C3: Armington elasticity of substitution by sector, GTAP

ID	Description	σ_A	ID	Description	σ_A
c1	Paddy rice	5.05	**c29**	Leather products	4.05
c2	Wheat	4.45	**c30**	Wood products	3.40
c3	Cereal grains	1.30	**c31**	Paper products, publishing	2.95
c4	Vegetables, fruit, nuts	1.85	**c32**	Petroleum, coal products	2.10
c5	Oil seeds	2.45	**c33**	Chemical, rubber, plastic products	3.30
c6	Sugar cane, sugar beet	2.70	**c34**	Mineral products	2.90
c7	Plant-based fibres	2.50	**c35**	Ferrous metals	2.95
c8	Crops	3.25	**c36**	Metals	4.20
c9	Bovine cattle, sheep & goats	2.00	**c37**	Metal products	3.75
c10	Animal products	1.30	**c38**	Motor vehicles & parts	2.80
c11	Raw milk	3.65	**c39**	Transport equipment	4.30
c12	Wool, silk-worm cocoons	6.45	**c40**	Electronic equipment	4.40
c13	Forestry	2.50	**c41**	Machinery & equipment	4.05
c14	Fishing	1.25	**c42**	Manufactures	3.75
c15	Coal	3.05	**c43**	Electricity	2.80
c16	Oil	5.20	**c44**	Gas manufacture, distribution	2.80
c17	Gas	17.20	**c45**	Water	2.80
c18	Minerals	0.90	**c46**	Construction	1.90
c19	Bovine meat prods	3.85	**c47**	Trade	1.90
c20	Meat products	4.40	**c48**	Transport	1.90
c21	Vegetable oils & fats	3.30	**c49**	Water transport	1.90
c22	Dairy products	3.65	**c50**	Air transport	1.90
c23	Processed rice	2.60	**c51**	Communication	1.90
c24	Sugar	2.70	**c52**	Financial services	1.90
c25	Food products	2.00	**c53**	Insurance	1.90
c26	Beverages & tobacco products	1.15	**c54**	Business services	1.90
c27	Textiles	3.75	**c55**	Recreational & other services	1.90
c28	Wearing apparel	3.70	**c56**	Public Admin, Defense, Education, Dwellings	1.90

Source: *Hertel & van der Mensbrugghe (2019)*

Description: GTAP model Armington elasticity of substitution (Hertel & van der Mensbrugghe, 2019). ID stands for identifier.

Use: Mapped onto the NICGE sector classifications. The mapped estimates were used to define the Armington elasticity in all non-manufacturing sectors.

Table C4: MFN tariffs for Exports by sector, United Kingdom

Identifier	Description	Export tariff
d1	Agriculture, Hunting, forestry & fishing	5.60%
d2	Mining & quarrying	0.00%
d3	Food, beverages & tobacco	5.00%
d4	Textiles & textile products, Leather	9.70%
d5	Wood & products of wood & cork	3.60%
d6	Pulp, paper, printing & publishing	0.10%
d7	Coke, refined petroleum & nuclear fuel	2.80%
d8	Chemicals & chemical products	2.20%
d9	Rubber & plastics	5.10%
d10	Other non-metallic minerals	3.30%
d11	Basic metals & fabricated metal	1.90%
d12	Machines, *etc.*	2.10%
d13	Electrical & optical equipment	1.60%
d14	Transport equipment	7.20%
d15	Manufacturing, *etc.*	1.70%
d16	Weighted average (by UK-EU trade)	3.30%

Source: *OBR (2018)*

Description: Estimated tariff rate by sector for UK exports to the EU under a World Trade Organisation, Most-favoured-nation trade deal (OBR, 2018).

Use: Mapped onto the NICGE sector classifications. These were used in the calculation of the % equivalent tariff rates for GB goods used as intermediate inputs by Northern Irish firms exporting to the EU.

Table C5: Proportion of goods and services sales by sector 2016, Northern Ireland

Identifier	Description	% Goods	% Services
e1	Agriculture, forestry & fishing	65.45%	34.55%
e2	Mining & quarrying	84.67%	15.33%
e3	Manufacturing	96.38%	3.62%
e4	Electricity, gas, steam & air conditioning supply	92.01%	7.99%
e5	Water supply, sewerage, waste management	38.28%	61.72%
e6	Construction	30.27%	69.73%
e7	Wholesale & retail trade	96.37%	3.63%
e8	Transport & storage	11.90%	88.10%
e9	Accommodation & food service activities	73.66%	26.34%
e10	Information & communication	8.55%	91.45%
e11	Real estate activities	4.15%	95.75%
e12	Professional, scientific & technical activities	20.23%	79.77%
e13	Administrative & support service activities	14.15%	85.85%
e14	Others	5.99%	94.01%

Source: *NISRA (2018)*

Description: Sector level estimate of the proportion of goods and services in total sales by sector in 2016 (NISRA, 2018).

Use: Mapped onto the NICGE sector classifications. These were used to proxy for the sector level proportion of goods and services in external trade. This is needed to compute the % equivalent external NTB for ROW and GB exports.

Note: Import and export specific numbers could not be found. Hence, this was used to proxy for the proportion of goods and services imported and exported from GB and ROW. In follow up studies, one should request this data from NISRA to more accurately model imports NTBs.

Table C6: Proportion of EU goods exports by sector 2019, Northern Ireland

Identifier	Description	EU exports
f1	Food & Live Animals	90.90%
f2	Beverages & Tobacco	56.80%
f3	Crude Materials	84.20%
f4	Mineral Fuels	95.80%
f5	Animal & Vegetable Oils	99.20%
f6	Chemicals	39.20%
f7	Manufactured Goods	84.00%
f8	Machinery & Transport	43.20%
f9	Miscellaneous Manufactures	58.70%
f10	Other commodities	99.90%

Source: *HMRC (2020)*

Description: Sector level estimate of the proportion of Northern Ireland's goods exported to the EU in 2019 as a fraction of total exports (HMRC, 2020).

Use: Mapped onto the NICGE sector classifications. The mapped estimates of the sector level proportion of goods exported to the EU relative to ROW were used in the calculation of the WTO-MFN % equivalent tariff rate for NI exports.

Table C7: Proportion of service imports and exports from the EU by sector 2017, Northern Ireland

Identifier	Sector	% Imports	% exports
g1	Primary & utilities	59.09%	98.53%
g2	Manufacturing	71.65%	53.19%
g3	Construction	83.78%	96.82%
g4	Wholesale & motor trades	89.30%	95.18%
g5	Retail (excluding motor trades)	78.37%	89.71%
g6	Transportation & storage	55.49%	85.57%
g7	Accommodation & food service activities	85.87%	78.74%
g8	Information & communication	38.74%	29.35%
g9	Financial & insurance activities	66.19%	41.32%
g10	Real estate activities	88.66%	82.58%
g11	Professional, scientific & technical activities	71.69%	60.52%
g12	Administrative & support service activities	51.16%	76.66%
g13	Other service sectors	73.24%	59.89%
g14	Travel-related trade	61.10%	-
	Total service imports/ exports	61.58%	70.48%

Source: *Author's calculation based on ONS (2019, 2020a)*

Description: Sector level estimates of the proportion of Northern Ireland's service imports and exports from and to the EU in 2017 as a fraction of total imports and total exports (ONS, 2019; ONS, 2020a).

Use: Mapped onto the NICGE sector classifications. These were used in the calculation of % equivalent NTBs for NI imports and exports to the ROW respectively.

Note: Due to confidentiality reasons, some of the sector specific numbers were not available. To estimate these, a method described in appendix D had to be employed. The underlined numbers are those which were estimated.

Table C8: Sector mapping

Code	NICGE	Young	Aspalter	GTAP	OBR	NISRA	HMRC	ONS
AFF	1	a1	-	c1-14*	d1	e1	f1	g1
OTP	2	a2-a5*	-	c15-18*	d2	e2	f3, f4*	g1
FAD	3	a7, a8	b1-b3	c19-26*	d3	e3	f2	g2
TLW	4	a9-a14, a18	b4-b8	c27-31*	d4-6	e3	f7	g2
CEP	5	a15	b9	c33	d8	e3	f5	g2
RCG	6	a16, a17, a19-a21	b10- b13	c33-37*	d9-11	e3	f6	g2
ELM	7	a23	b14, b15	c40	d13	e3	f9	g2
MOM	8	a22, a24-a27	b16-b18	c38-39, c41-42*	d12, d14, d15	e3	f9	g2
ETD	9	a16, a30, a31*	-	c32, c43-44*	d7	e4	f10	g13
GDS	10	a34	-	c55	d16	e9	f10	g7
WSW	11	a22	-	c45	d16	e5	f10	g13
CON	12	a6	-	c46	d16	e6	f10	g3
WRT	13	a32	-	c47	d16	e7	f10	g4, g5
IAC	14	a29	-	c51	d16	e10	f10	g8
FIN	15	a33	-	c52-53*	d16	e14	f10	g9
RES	16	a33	-	c54-55*	d16	e11, e12	f10	g10, g11
PUB	17	a35	-	c56	d16	e13	f10	g12
OTS	18	a34, a28*	-	c48-50, c55*	d16	e8	f10	g13

Source: *Author's analysis*

Description: This Table displays the mapping of sector categories onto NICGE's eighteen sectors. The identifiers relate to Tables C1-C7.

Note: Where feasible, sectors were matched following NACE classifications. When multiple categories are mapped onto one of the NICGE sector categories, a weighted average is computed taking into account the proportion of production in the given categories in Northern Ireland. Numbers with an asterisk denote categories where weighted averages could not be computed. In these cases, a mean was used. Underlined numbers are those for which matching was imprecise (e.g. f10 is an 'other commodities' category used for service heavy sectors).

D: Expected Value method

ONS (2019, 2020a) data for service exports to the EU and ROW (excl. EU) is not available for all sectors mapped onto NICGE. This is since some of the data is unreported for confidentiality reasons. As only some sectors for Wales and NI are missing and all the data for other regions' sectors in the UK are known, it was possible to compute the quantity of sector specific service exports to the EU and ROW (excl. EU) for Wales and NI together using Table D1 and equation D1.

Table D1: Service exports by region 2017

Region (r)	NE		NW		YH		EM		WM		EE		LO		SE		SW		WA		SC		NI		UK	
sector (j) / export region (x)	EU	ROW	EU	ROW	EU	ROW	EU	ROW	EU	ROW	EU	ROW	EU	ROW	EU	ROW	EU	ROW	EU	ROW	EU	ROW	EU	ROW	EU	ROW
Primary and utilities	6	1	30	3	16	19	28	9	6	11	23	9	8	3	16	9	23	7	..	..	108	767	..	..	298	840
Manufacturing	820	253	769	682	203	215	250	301	290	304	638	667	362	613	1,289	1,896	379	501	..	..	947	1,166	..	..	6,581	8,802
Construction	11	6	26	21	11	7	28	10	9	13	44	101	136	187	54	46	13	18	8	4	36	46	240	8	615	467
Wholesale and motor trades	42	5	461	872	82	22	46	15	168	64	172	44	1,928	1,543	726	229	117	101	..	..	99	27	..	..	3,916	2,937
Retail (excluding motor trades)	55	25	170	81	118	57	122	52	150	56	159	81	539	546	237	121	140	63	..	..	129	60	..	..	1,883	1,171
Transportation and storage	183	235	997	1,469	520	617	363	409	566	609	820	1,164	2,584	4,248	1,957	3,409	593	955	..	..	916	1,501	..	..	10,038	14,975
Accommodation and food service activities	250	258	732	775	509	532	427	447	490	505	562	585	1,152	1,275	929	974	912	980	..	..	782	860	..	..	7,121	7,592
Information and communication	168	261	371	697	195	408	309	425	571	635	744	1,073	10,833	14,904	3,984	4,436	459	519	121	101	361	682	156	376	18,272	24,517
Financial and insurance activities	518	781	2,008	3,052	1,238	1,808	593	885	1,349	2,045	1,307	2,060	15,018	24,128	2,190	4,053	1,365	2,120	905	1,437	2,370	3,900	336	477	29,197	46,746
Real estate activities	5	6	13	21	12	15	3	4	12	21	21	36	152	252	108	25	15	26	..	..	9	15	..	..	356	426
Professional, scientific and technical activities	195	290	507	947	283	510	286	570	265	527	848	2,184	6,784	13,587	3,914	6,860	287	695	87	221	1,750	1,811	192	125	15,398	28,327
Administrative and support service activities	232	285	848	1,366	476	531	461	462	367	500	1,393	1,466	4,695	5,048	2,138	1,961	851	1,218	..	..	740	951	..	..	12,546	14,203
Other services	258	376	826	1,507	476	742	421	621	766	1,229	529	717	2,434	3,623	1,320	1,831	437	667	312	450	700	1,154	22	14	8,502	12,932
All sectors	2,743	2,782	7,760	11,494	4,140	5,483	3,336	4,211	5,009	6,518	7,260	10,188	46,624	69,956	18,862	25,849	5,590	7,870	2,877	5,382	8,946	12,940	1,576	1,264	114,723	163,935

North East	**NE**
North West	**NW**
Yorkshire and The Humber	**YH**
East Midlands	**EM**
West Midlands	**WM**
East of England	**EE**
London	**LO**
South East	**SE**
South West	**SW**
Wales	**WA**
Scotland	**SC**
Northern Ireland	**NI**
United Kingdom	**UK**

Source: *ONS (2019)*

$$(WA + NI)_{j,x} = UK_{j,x} - \sum_{r} r_{j,x} \qquad \text{(D1)}$$

Where: j=sector; x=export region (EU/ROW); r=UK region excluding Wales and NI; r_j=region total for sector j; $UK_{j,x}$= the UK total service export by sector and x; $(WA + NI)_{j,x}$= total service export by sector and x for Wales and NI together.

Equation D1 defines the service exports for each sector (j) and export region (x) for Wales and NI together. Using Table D1 and equation D1 the following numbers are found:

Table D2: NI & Wales service exports by destination 2017

Region (r)	NI & Wales	
sector (j) / export region (x)	EU	ROW
Primary & utilities	34	2
Manufacturing	634	2,204
Construction	247	12
Wholesale & motor trades	75	15
Retail (excluding motor trades)	64	29
Transportation & storage	539	359
Accommodation & food service activities	376	401
Information & communication	277	477
Financial & insurance activities	1,241	1,914
Real estate activities	6	5
Professional, scientific & technical activities	279	346
Administrative & support service activities	345	415
Other services	335	465
All sectors	4,452	6,644

Source: *Authors' calculations using ONS (2019) and equation D1*

As total service exports to the EU and ROW (excl. EU) were available for some sectors in NI and Wales, and the totals for all sectors were also available for NI and Wales it was possible to compute the total remaining amount of service exports to the EU and ROW (excl. EU) for NI and Wales separately using equation D2 and Table D1.

$$\sum_{i} R_{i,x} = \sum R_x - \sum_{l} R_{l,x} \qquad \text{(D2)}$$

Where: i= the missing sectors for NI and Wales; *l*= the known sectors for NI and Wales; *R*= NI or Wales; $\sum R_x$= total service exports in R to x (this is 1,576 for NI service exports to the EU); $\sum_l R_{l,x}$ = the sum of total service exports from R to x of the known sectors j; $\sum_i R_{i,x}$ = the sum of total service exports from R to x to the missing sectors.

Using equation D2, the numbers at the bottom of Table D3 can be derived:

Table D3: Total service exports in the missing sectors for NI and Wales by destination 2017

Region (r)	**WA**		**NI**	
sector (j) / export region (x)	**EU**	**ROW**	**EU**	**ROW**
Primary & utilities	..	..	..	..
Manufacturing	..	..	..	..
Construction	8	4	240	8
Wholesale & motor trades	..	..	..	..
Retail (excluding motor trades)	..	..	..	..
Transportation & storage	..	..	..	..
Accommodation & food service activities	..	..	..	..
Information & communication	121	101	156	376
Financial & insurance activities	905	1,437	336	477
Real estate activities	..	..	..	..
Professional, scientific & technical activities	87	221	192	125
Administrative & support service activities	..	..	..	..
Other services	312	450	22	14
All sectors	2,877	5,382	1,576	1,264
Total remaining sectors (TRI)	**1,444**	**3,169**	**630**	**264**

Source: *Author's calculations using equation D2 and Table D1*

Thus, it was possible to determine what proportion of the remaining service exports to the EU and ROW were from NI using equations D3 and D4:

$$\%\, NI_{EU} = \frac{\mathrm{TRI}_{NI,EU}}{\mathrm{TRI}_{NI,EU} + \mathrm{TRI}_{WA,EU}} = \frac{630}{630 + 1{,}444} = 30.4\% \quad \text{(D3)}$$

$$\%\, NI_{ROW} = \frac{\mathrm{TRI}_{NI,ROW}}{\mathrm{TRI}_{NI,ROW} + \mathrm{TRI}_{WA,ROW}} = \frac{264}{3{,}169 + 264} = 7.7\% \quad \text{(D4)}$$

By calculating the proportion of the missing sectors' service exports to the EU and ROW (excl. EU) which are in NI (relative to NI and Wales) and multiplying these proportions for each region (EU, ROW excl. EU) by the known quantity of sector specific exports to the EU and ROW (excl. EU) for Wales and NI together, an expected quantity of sector specific exports to the EU and ROW (excl. EU) for NI could be computed. This is shown in Table D4:

Table D4: Total proportion of service exports to the EU in the missing sectors for NI 2017

Region (r)	NI		NI & Wales		% NI		NI		
sector (j) / export region (x)	EU	ROW	EU	ROW	EU	ROW	EU	ROW	% EU
Primary & utilities	..	..	34.0	2.0	30.4%	7.7%	10.3	0.2	98.5%
Manufacturing	..	..	634.0	2204.0	30.4%	7.7%	192.7	169.5	53.2%
Construction	240.3	7.9	247.0	12.0	..	..	240.3	7.9	96.8%
Wholesale & motor trades	..	..	75.0	15.0	30.4%	7.7%	22.8	1.2	95.2%
Retail (excluding motor trades)	..	..	64.0	29.0	30.4%	7.7%	19.5	2.2	89.7%
Transportation & storage	..	..	539.0	359.0	30.4%	7.7%	163.8	27.6	85.6%
Accommodation & food service activities	..	..	376.0	401.0	30.4%	7.7%	114.3	30.8	78.7%
Information & communication	156.0	375.6	277.0	477.0	..	..	156.0	375.6	29.3%
Financial & insurance activities	335.5	476.6	1241.0	1914.0	..	..	335.5	476.6	41.3%
Real estate activities	..	..	6.0	5.0	30.4%	7.7%	1.8	0.4	82.6%
Professional, scientific & technical activities	192.2	125.4	279.0	346.0	..	..	192.2	125.4	60.5%
Administrative & support service activities	..	..	345.0	415.0	30.4%	7.7%	104.8	31.9	76.7%
Other services	21.5	14.4	335.0	465.0	..	..	21.5	14.4	59.9%

Source: *Authors' calculations using ONS (2019) and equations D1-D4*

Note that all shaded areas are expected values. Although these expected values are not perfect, using this method takes advantage of all publicly available data to compute sector specific quantities of service exports to the EU and ROW (excl. EU) for NI.

The same method was employed for sector specific missing values in NI for service imports from the EU and ROW. Table D5 Provides the estimates:

Table D5: Total proportion of service imports from the EU in the missing sectors for NI 2017

Sector	% EU
Primary & utilities	59.1%
Manufacturing	71.6%
Construction	83.8%
Wholesale & motor trades	89.3%
Retail (excluding motor trades)	78.4%
Transportation & storage	55.5%
Accommodation & food service activities	85.9%
Information & communication	38.7%
Financial & insurance activities	66.2%
Real estate activities	88.7%
Professional, scientific & technical activities	71.7%
Administrative & support service activities	51.2%
Other services	73.2%

Source: *Authors' calculations using equations D1-D4 and ONS (2020a)*

E: Sensitivities

E1. Elasticity of substitution between capital and labour

Table E1: pp difference in long run GDP and intermediate inputs for different aggregate σ_κs, FTA

σ_κ	GDP	Intermediate inputs GB	Intermediate inputs ROW
0.3	-0.1%	0.0%	0.0%
0.4	0.0%	0.0%	0.0%
0.5	0.1%	0.0%	0.0%
0.6	0.1%	0.0%	0.0%

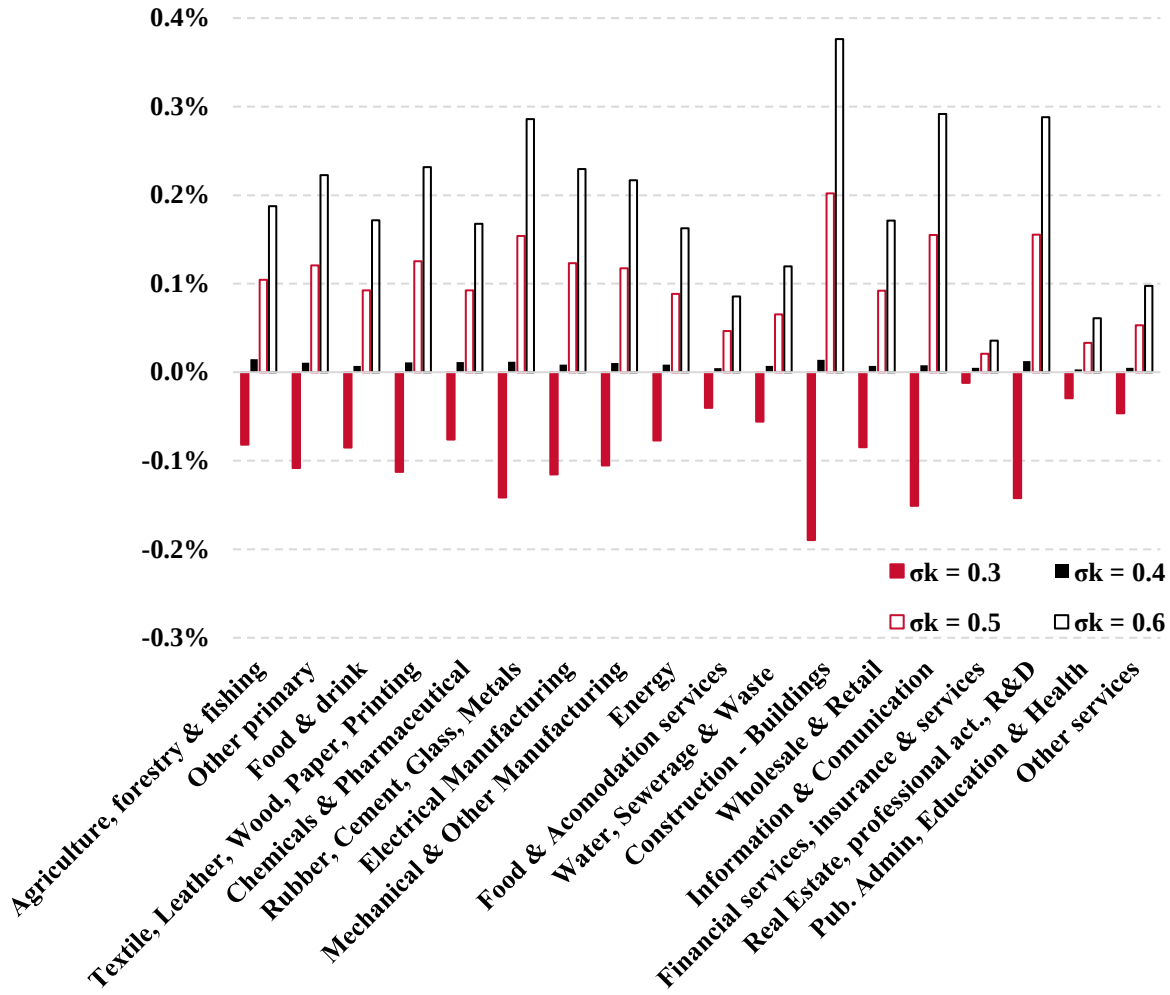
Source: *Authors' calculations*

Description: Table E1 displays the percentage point (pp) difference in GDP and intermediate inputs from GB and ROW relative to the central FTA scenario depending on the value of the elasticity of substitution between capital and labour (σ_κ). σ_κ is set equal to 0.3, 0.4, 0.5 and 0.6

Use: This sensitivity check was completed to determine whether the paper's conclusions were dependent on the choice of σ_κ. Table E1 suggests that the key macroeconomic results were not dependent on σ_κ.

Note: The MFN scenario is not displayed as the sensitivity check displays the same pattern. σ_κ is set equal in all sectors in the sensitivity checks.

Figure E1: Sector level pp difference in long run value added relative to the central FTA scenario



Source: *Author's Analysis*

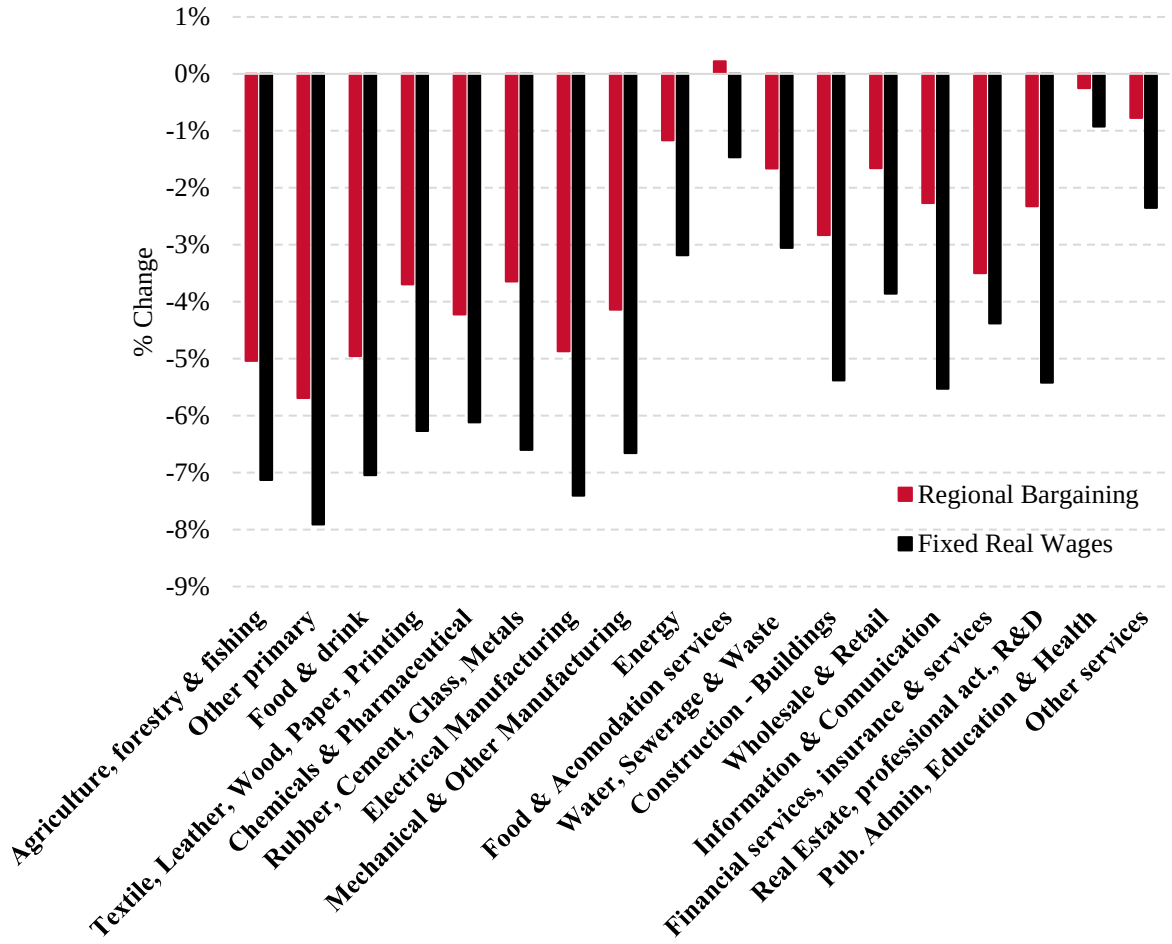
Description: Figure E1 displays the percentage point difference in value added by industry relative to the central FTA scenario depending on σ_κ .

Use: This sensitivity check was completed to determine whether the paper's conclusions were dependent on the choice of σ_κ. Figure E1 suggests that some sector level results are slightly more dependent on σ_κ than the macroeconomic results but the difference is relatively small.

Note: The MFN scenario is not displayed as the sensitivity check displays the same pattern. σ_κ is set equal in all sectors in the sensitivity checks.

E2. Food and Accommodation sector

Figure E2: Value added by sector in the FTA scenario under different labour market assumptions



Description: Figure E2 displays the percentage change from the no-Brexit baseline in value added by sector for the FTA scenario. The red rectangles represent the central FTA scenario under the downward sloping wage curve assumption. The black rectangles represent the central FTA scenario when real wages are fixed.

Use: This sensitivity check was completed to determine why the food and accommodation sector's value added increased relative to a no-Brexit baseline under MFN and FTA scenarios. Figure E2 suggests that the increase in value added is due to decreased wages.

Note: The MFN scenario is not displayed as the sensitivity check displays the same pattern.

E3. Optimistic and Pessimistic scenarios of the FTA

Table E2: Long-term economic impact on key macroeconomic indicators in the FTA Scenario

GDP	CPI	Consumption	Real wage
-2.6%	2.3%	-2.5%	-3.9%
(-1.5%, -3.5%)	(1.4%, 3.3%)	(-1.5%, -3.3%)	(-2.3%, -5.1%)
Employment	**Investment**	**Import**	**Export**
-1.2%	-3.3%	-4.4%	-7.4%
(-0.6%, -1.6%)	(-2.0%, -4.5%)	(-2.6%, -5.9%)	(-4.4%, -10.2%)
Exports		**Intermediate imports**	
GB	**ROW**	**GB**	**ROW**
-6.1%	-8.6%	-5.9%	0.5%
(-3.9%, -8.2%)	(-4.8%, -12.0%)	(-3.8%, -7.9%)	(0.9%, 0.5%)

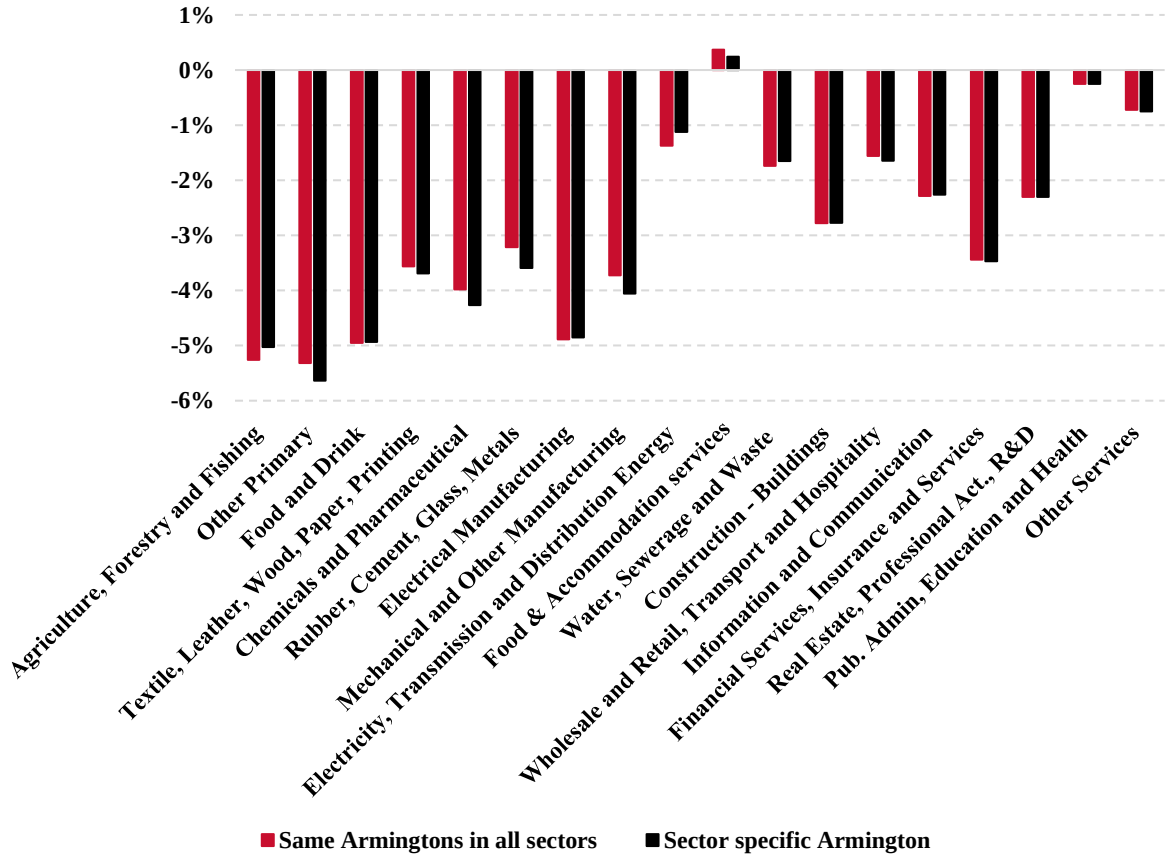
Results from simulations

Description: Table E2 displays the long run response to the FTA under a central, pessimistic and optimistic scenario for the NTBs. These are defined using HMG's (2018) goods and service specific estimates of NTBs. The first term in the brackets in table E2 corresponds to the lower bound estimate (optimistic) and the second term the upper bound estimate (pessimistic).

Use: This sensitivity check was completed to determine by how much results vary with different NTB estimates. Although there is a large variation in the figures reported it must be noted that even in the most optimistic scenario, GDP and consumption fall by 1.5%. In a pessimistic scenario, GDP and consumption could fall by over 3.3%.

E4. Value added by sector under common Armington elasticity compared to sector specific ones

Figure E3: Value added by sector in the FTA scenario under different Armington assumptions



Description: Figure E3 displays the percentage change from the no-Brexit baseline in value added by sector for the FTA scenario. The red rectangles represent the central FTA scenario when Armington elasticities are equal to 2 in all sectors. The black rectangles represent the central FTA scenario with sector specific Armington elasticities.

Use: This sensitivity check was completed to determine if the sector specific value added were sensitive to the choice of the Armington elasticities. Figure E3 suggests that the results are not very sensitive to the choice of the Armington elasticities.

Note: The MFN scenario is not displayed as the sensitivity check displays the same pattern.