Preparation of 2019 USAGE-TERM and Application of a Dynamic Version to a Foot-and-Mouth Outbreak scenario

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Abstract

The USAGE-TERM database has been updated to 2019. The tasks commences with a dated national CGE database. BEA's supply-use matrices for 2017 provide updates to industry technologies. National accounts data at the national and state level for 2019 provide broad sector targets for updates and regional industry activity shares. International trade data by port for 2019 are used to update international merchandise trade in the database.

As in previous USAGE-TERM databases, agricultural census data provides estimates of regional outputs for disaggregated crops and livestock. International data on the location and type of generation of power stations enable a split of electricity into different types of generation.

An innovation in this version of USAGE-TERM is a split of a subset of national commodities. The split distinguishes commodities reliant on water transport in the Mississippi Valley and Snake-Columbia river systems from the same commodities reliant on land transport elsewhere.

Keywords Regional CGE modelling

JEL codes: C68, D57, D58, R15

1. Preparation of updated USAGE-TERM database

Glyn Wittwer

1.1 Introduction

This paper covers the preparation of an updated CGE database at both the national and regional levels. The task combines new data and revised sectors with existing customized sectors in the older national database. This paper outlines a methodology for devising an updated multi-regional database. The tasks entails preparing a matrix of regional activity estimates at the county level for more than 400 sectors. From this, aggregation of the activity estimates enables us to create a bottom-up regional master database of manageable dimensions.

Starting a national database update (sections 1.2 to 1.4)

The preferred starting point for any CGE database is a publicly available set of input-output tables. The initial national database of the USAGE model, from which USAGE-TERM is prepared, is based on BEA supply-use tables from 2005.[1] The MAKE matrix, which provides the value of commodity outputs of each industry, is diagonalized, so that each industry in the database produces a unique commodity. Tasks undertaken at the national level include altering farm detail so that cost structures relate to commodity outputs rather than farm type. The national USAGE model includes dummy industries to depict tourism activity. The national model also includes a split of air transport and water transport to distinguish between activities in the domestic economy and those elsewhere. Electricity generation is split into different types of generation. Scenarios regarding the transition to renewables may also be relevant in some projects. There are also marked differences in generating technologies between regions. A 2005 national CGE database was updated to 2013 using national accounts data and international merchandise trade data. Wittwer (2017a) details data sources and preparation of a regional CGE database for the U.S. economy.

Several sources enable splitting of the national database into regions. Census data from 2010 provided county level employment head counts used to estimates shares of national economic activity at the NAICS four digit industry level (Wittwer 2017a, chapter 10). State level BEA national accounts data include value-added outputs for 21 broad sectors. International merchandise trade data by port provide regional activity targets at the two-digit NAICS level. A version of the gravity assumption is used once estimates of regional supplies and demands are in place, to devise an inter-regional trade matrix.

Starting a regional database update (section 1.5 to 1.7)

The objective of the exercise is to prepare an updated multi-regional CGE database based on 2019 data, the most recent full year prior to COVID disruptions. Selecting suitable regions is not a straightforward matter in the US case. Representation at the state level includes California, whose economy is larger than that of all but a handful of countries. Sub-state depiction is desirable in many model applications.

Moreover, different projects require markedly different sectoral and regional representation. One project for which the updated database was devised was a Food and Agriculture

[1] See https://www.bea.gov/industry/input-output-accounts-data.

Consequence of Adverse Events Tool. In the sectoral dimension, USAGE-TERM routinely includes different crops and types of livestock, rather than the farm-type basis of BEA supply-use tables. For this project, an appropriate master database utilizes the disaggregation of agricultural and food sectors. In the regional dimension, 321 USDA agricultural regions plus 26 non-agricultural regions have been included in the master database.

Other potential projects may require a different sectoral and regional emphasis. An example is the update of a GRAD-E-CAT kit (Dixon *et al*., 2017). This kit has been designed to depict the economic impacts of hypothetical adverse events. The events occur in urban areas. In the initial development of GRAD-E-CAT, regions were based on congressional districts. This entailed a complication, as congressional districts do not respect usual statistical boundaries. For the GRAD-E-CAT update, representation will switch to metropolitan areas, which are combinations of counties for which data are available. Aggregation from counties to metropolitan areas is straightforward.

Given the requirement that different projects require markedly different sectoral and regional representation, an early decision in the database updating task was to prepare an updated county level matrix of industry activities. This consists of estimates of value-added activities for more than 400 sectors in more than 3000 counties. This contains more sectors and more regions than will be used in any prepared master database. Master databases at the regional level use an aggregated national CGE database combined with an aggregation of regional activities. Without aggregation, it would be extremely difficult if not computationally impossible to generate a bottom-up USAGE-TERM master database.

Dynamic CGE modelling (section 1.8)

We find it practical to depict some scenarios using a timeline, which involves dynamic modelling. The aggregation procedure for dynamic modelling is more complex than that required for comparative static modelling. Section 1.8 examines some of the tasks involved in preparing a dynamic model and outlines a method to minimize dynamic instability

1.2 National database development

The starting national database includes 513 sectors for 2013. This is based on BEA supply-use tables with modifications covering farm sectors, electricity sectors, tourism sectors and transport sectors as outlined earlier. The national database update procedure initially uses national accounts data and international trade data to target 2019 levels. This relies on BEA (https://www.bea.gov/data/gdp/gdp-industry) and online international trade data (https://usatrade.census.gov/). A major task concerns mapping available data to sectors in the database.

Imposing new values on an existing database requires a program to ensure that the amended database is balanced. Mark Horridge of the Centre of Policy Studies devised a program called ADJUSTER for this task (see https://www.copsmodels.com/archivep.htm TPMH0058). The ADJUSTER program is designed to scale a complex CGE database. Scaling procedures based on RAS are sufficient to balance a single two-dimensional matrix, such as may be used in a SAM-based CGE model. ADJUSTER is based on database structure of the ORANI-G model and enables balancing over multi-dimensional matrices.

The ADJUSTER program lists all the CGE database matrices to be scaled. It includes formulae for potential target values such as GDP and its components on the income and expenditure sides. The balance conditions to be enforced are written in the program. In a national model, costs summed across industries for each commodity must equal commodity sales. Scale factors are written into the model. These are associated with relevant matrices. In ADJUSTER program runs, a particular target (i.e., exogenous) value is accommodated by making a scaling factor endogenous.

In GEMPACK code, the core CGE model requires some rewriting to devise a levels programs such as ADJUSTER. The program deals with numeric identities rather than economic theory. Each core CGE database Coefficient in the CGE model code is relabelled as a levels Variable. Each Formula is relabelled as "Formula&Equation"

National accounts data are available for 66 sectors. Therefore, we require a mapping from the 513 sectors of the initial database to the national accounts sectors, in order to hit national accounts target with the ADJUSTER program. Similarly, merchandise export and import data require mappings between the merchandise subset of the 513 sectors of the initial database and the sectors of international trade data. Within ADJUSTER, scaling variables are endogenised so that we can hit various targets including trade values.

A subsequent task depends on regional information on various activities: the 2013 USAGE database included water transport using commodities. A key insight from evaluation of Commodity Flow Survey data is that for relevant commodities, regions should be split between those relying heavily on water transport and those relying mainly on land transport (Wittwer 2017). The reason for the distinction is that an underlying assumption in preparing a multi-regional database is that technologies are identical in each region. Knowing that some commodities are transported via waterways in the Mississippi Basin and Columbia-Snake River System but not elsewhere, the identical technology assumption is only defensible if some commodities are split into two. This is the case for wheat, corn, soybean, coal and sugar processing among others.[2] Regional activity shares, distinguishing between water transport using regions and other regions, provide splitting weights. Agricultural census data from 2017 provided agricultural sector activities used in the initial split. Now, for example, there are two wheat commodities, one transported by land, the other by water. Regional activity shares will divide water-transported wheat among regions of the Mississippi Basin and Snake-Columbia system, and land-transported wheat elsewhere.

[2] The split sectors in the fully disaggregated database are (table 1.1 commodity numbers in parentheses): Corn (12 & 13); Rice (23 & 24); Sorghum (25 & 26); Soybean (27 & 28); Wheat (34 & 35); Forestry & logging (36 & 37); Coal (43 & 44); Iron ores (45 & 46); Gold & other metal ores (47 & 48); Stone (50 & 51); Sand & gravel (52 & 53); Other non-metallic minerals (54 & 55); Flour & malt (83 & 84); Wet corn milling (87 & 88); Soybean processing (89 & 90); Manufactured sugar (94 & 95); Fruit & vegetable processing (100 & 101); Breweries (126 & 127); Sawmills (152 & 153); Veneer & plywood (156 & 157); Other wood products (160 & 161); Petroleum refineries (185 & 186); Other petroleum & coal products manufacturing; Asphalt products (188 & 189); Petrol, oil & grease products (190 & 191); Other petroleum & coal products (192 & 193); Industrial gas (195 & 196); Synthetic dyes (197 &198); Other inorganic chemicals (199 & 200); Plastic products (202 & 203); Synthetic rubber (204 & 205); Non-cellular fiber (207 & 208); Pesticides (211 & 212); Miscellaneous chemical products (224 & 225); Cement (245 & 246); Lime (251 & 252); Ground mineral earth (256 & 257); Iron & steel mills (260 & 261); Alumina (264 & 265); Automobiles (396 & 397); and Vehicle parts (403 & 404). Many of these commodities are aggregated in aligning with the most recent (2017) BEA supply-use tables, as shown in the mapping in table 1.1.

Using the most recent supply-use tables

BEA released 2017 supply-use tables in September 2023. Since the updating and splitting tasks above had already been completed by the time the new tables emerged, the choice then was either to start again or integrate information from the new BEA tables into the CGE database. The latter path was chosen, thereby avoiding the need to revisit database amendments to depict agricultural sectors, and the USAGE treatment of water and air transport and tourism.

A major task was to align sectors in the new BEA table with the existing national CGE database. Table 1.1 shows a mapping from the newly split 554 sectors of the existing database to 406 sectors (including a water transport split, or 379 sectors excluding this split) based on the most recent supply-use tables. We use the 406 sector data for further processing.

The 554 sector representation, based on a water transport split of the 513 sector 2013 database, includes some sectoral representation more detailed than is likely to be used in most practical policy analysis. For example, there are 13 construction sectors, as shown for sectors 68 to 80 in table 1.1. These have been aggregated to three, residential, non-residential and civil construction. The 2017 supply-use tables include 12 construction sectors. In a project in which additional detail on construction may be helpful, we could use information from the 12 construction sectors to modify or split the amended database. National accounts data include a single construction sector target for the update to 2019.

Some sectors other than those warranting particular attention, such as agricultural, electricity generation and tourism sectors, are more aggregated in the 2017 supply-use tables than earlier versions. For example, milk and butter are combined to align with the new tables, whereas they were separate in older tables. Structural change has diminished the importance of some sectors in the national economy. For example, the BEA reduced TCFs, covered by 19 sectors (133 to 151 in table 1.1), to 8 sectors in the most recent supply-use tables. The revised database includes these 8 sectors. In summary, the revised 2019 national database is aggregated to 406 sectors. It includes technologies revised using the BEA 2017 USE table, as is explained in the following section. Most of the aggregation from 554 to 406 reflects the aim to update using sector-specific data.

Table 1.1: Mapping amended 406 to previous 554 sectors (1)

	Amend406	Prev554		Amend406	Prev554		Amend406	Prev554
1	HayForage	HayForage	51	StoneN	StoneN	101	FrtVegCDryN	FrtVegCDryN
2	Almonds	Almonds	52	SandGravlOTW	SandGravelW	102	MilkButter	Milk
3	Apples	Apples	53	SandGravlOTN	SandGravelN	103	MilkButter	Butter
4	OthFruitNuts	OthFruitNuts	54	SandGravlOTW	OthNonMetlW	104	Cheese	Cheese
5	Vegetables	Vegetables	55	SandGravlOTN	OthNonMetlN	105	DCEDairy	DCEDairy
6	OthBroadAcre	OthBroadAcre	56	OilGasDrill	OilGasDrill	106	IceCream	IceCream
7	PoultryEggs	PoultryEggs	57	MiningSupp	OilGasSupp	107	MeatProds	AnSlauXPlt
8	SugarCane	SugarCane	58	MiningSupp	OthMineSupp	108	MeatProds	Meat
9	OilSeeds	OilSeeds	59	GeothermGen	GeothermGen	109	MeatProds	RendByprod
10	BeefCattle	BeefCattle	60	CoalsGen	CoalsGen	110	PoultryProc	PoultryProc
11	MiscelAgri	MiscelAgri	61	GasGen	GasGen	111	Seafood	Seafood
12	CornW	CornW	62	HydroGen	HydroGen	112	BakingProds	FrozCake
13	CornN	CornN	63	NuclearGen	NuclearGen	113	BakingProds	Bread
14	Cotton	Cotton	64	RenewGen	RenewGen	114	CookiPastTrt	Cookies
15	DairyCattle	DairyCattle	65	ElecDist	ElecDist	115	BakingProds	PrepDough
16	Grapes	Grapes	66	NatGasDist	NatGasDist	116	CookiPastTrt	Pasta
17	Nursery	Nursery	67	WaterSewage	WaterSewage	117	CookiPastTrt	Tortilla
18	Hogs	Hogs	68	NonResConstr	NRes1Nonfarm	118	SnackFood	NutsPnutBtr
19	OthFruit	OthFruit	69	ResidCnstrct	MulResNonf	119	SnackFood	OthSnack
20	OthLivestock	OthLivestock	70	ResidCnstrct	ResAddNonf	120	CoffTea	CoffTea
21	Citrus	Citrus	71	ResidCnstrct	FarmRes	121	FlavorSyrup	FlavorSyrup
22	Potatoes	Potatoes	72	NonResConstr	ManIndBldg	122	SeasDrsng	MayoDrsng
23	RiceW	RiceW	73	NonResConstr	CommInstBldg	123	SeasDrsng	Spices
24	RiceN	RiceN	74	CivConstruct	HwyBrdgCons	124	OthrFoodMf	OthrFoodMf
25	SorghumW	SorghumW	75	CivConstruct	WatSewerCons	125	SoftDrinks	SoftDrinks
26	SorghumN	SorghumN	76	NonResConstr	OthNewCons	126	BreweriesW	BreweriesW
27	SoybeanW	SoybeanW	77	ResidCnstrct	MRresidence	127	BreweriesN	BreweriesN
28	SoybeanN	SoybeanN	78	NonResConstr	MRNonres	128	Wineries	Wineries
29	Strawberries	Strawberries	79	CivConstruct	MRstreets	129	Distilleries	Distilleries
30	Sugarbeet	Sugarbeet	80	NonResConstr	OthMRCons	130	TobacProds	TobStmDry
31	Tobacco	Tobacco	81	DogCatFood	DogCatFood	131	TobacProds	Cigarette
32	Tomatoes	Tomatoes	82	OthAnFood	OthAnFood	132	TobacProds	OthTobacco
33	Turkeys	Turkeys	83	FlourMaltW	FlourMillW	133	FiberYarn	FiberYarn
34	WheatW	WheatW	84	FlourMaltN	FlourMillN	134	Fabrics	BroadFabric
35	WheatN	WheatN	85	FlourMaltN	RiceMill	135	Fabrics	NarrowFabric
36	ForstLogging	LoggingW	86	FlourMaltN	Malt	136	Fabrics	NonWovFabric
37	ForstLogging	LoggingN	87	WetCornMillW	WetCornMillW	137	Fabrics	KnitFabric
38	ForstLogging	ForTimber	88	WetCornMillN	WetCornMillN	138	TxtFabFinCoa	TxtFabFinish
39	ForstLogging	Fishing	89	SoyOthProc	SoyProcW	139	TxtFabFinCoa	FabCoating
40	FishHuntTrap	HuntTrap	90	SoyOthProc	SoyProcN	140	Carpet	Carpet
41	AggForSupp	AggForSupp	91	SoyOthProc	OthOilseed	141	CurtainLinen	CurtainLinen
42	OilGas	OIlGas	92	FatsOils	FatsOils	142	OthTextile	TxtBagCanvs
43	CoalW	CoalW	93	BrkCereal	BrkCereal	143	OthTextile	TireCord
44	CoalN	CoalN	94	SugarManufW	SugarManufW	144	OthTextile	MiscTxtl
45	MetalOresW	IronOreW	95	SugarManufN	SugarManufN	145	Apparel2	SheerHosiery
46	MetalOresN	IronOreN	96	SugarManufN	ConfCacao	146	Apparel2	OthHosiery
47	CopNickMine	CopNickMine	97	SugarManufN	ConfChoc	147	Apparel2	Apparel
48	MetalOresW	GoldOthMetlW	98	SugarManufN	ConfNonchoc	148	Apparel2	AprlAccess
49	MetalOresN	GoldOthMetlN	99	FrozFood	FrozFood	149	LeathFwear	Leather
50	StoneW	StoneW	100	FrtVegCDryW	FrtVegCDryW	150	LeathFwear	Footwear

Note: Corn, Sorghum, Soybean, Wheat etc. are divided into water transport using (W) and non-using (N)

Table 1.1: Mapping amended 406 to previous 554 sectors (2)

	Amend406	Prev554		Amend406	Prev554		Amend406	Prev554
151	LeathFwear	OtherLeath	201	OthOrgChem	OthOrgChem	251	LimeGypsum	LimeW
152	SawWoodPrsv	SawmillsW	202	PlasticsW	PlasticsW	252	LimeGypsum	LimeN
153	SawWoodPrsv	SawmillsN	203	PlasticsN	PlasticsN	253	LimeGypsum	Gypsum
154	SawWoodPrsv	WoodPrsrv	204	SynthRubberW	SynthRubberW	254	Abrasives	Abrasives
155	OthWoodPrd	RecWoodPrd	205	SynthRubberN	SynthRubberN	255	CutStonePrd	CutStonePrd
156	VeneerPlwdW	VeneerPlwdW	206	InvitroDiag	CelFiber	256	GrdMinEarthW	GrdMinEarthW
157	VeneerPlwdN	VeneerPlwdN	207	BioNonDiagW	NoncelFiberW	257	GrdMinEarthN	GrdMinEarthN
158	OthWoodPrd	WoodTruss	208	BioNonDiagN	NoncelFiberN	258	MinWool	MinWool
159	OthWoodPrd	WoodWndoDoor	209	Fertilizer	NitroFert	259	MscNonMetMin	MscNonMetMin
160	OthWoodPrd	WoodSawPlaW	210	Fertilizer	PhosphFert	260	IronStlMillW	IronStlMillW
161	OthWoodPrd	WoodSawPlaN	211	PesticideW	PesticideW	261	IronStlMillN	IronStlMillN
162	Millwork	Millwork	212	PesticideN	PesticideN	262	SteelPrds	Ferroalloy
163	OthWoodPrd	WoodCntnr	213	PharmaMeds	PharmaMeds	263	SprnWirePrd	SteelWire
164	OthWoodPrd	MfMoblHome	214	Paint	Paint	264	AluminaW	AluminaW
165	OthWoodPrd	PrefWdBldgs	215	Adhesives	Adhesives	265	AluminaN	AluminaN
166	OthWoodPrd	MscWoodProd	216	SoapCleaning	SoapDetrgnt	266	Aluminum	Aluminum
167	PulpMills	PulpMills	217	SoapCleaning	Polish	267	Aluminum	AlumSheet
168	PaperMills	PaperMills	218	SoapCleaning	SurfAgent	268	Aluminum	OthAlum
169	PprContainer	PprContainer	219	ToiletPrep	ToiletPrep	269	NonFeSmelt	CopperSmelt
170	PprBrdMills	FlxPkingFoil	220	Ink	Ink	270	NonFeSmelt	NonferrMetl
171	PprBrdMills	CoatPprbrd	221	OtherChem	Explosives	271	CoprRollDraw	CoprRollDraw
172	PprBrdMills	CoatPprPck	222	OtherChem	ResinComp	272	NonFeSmelt	NonferrShape
173	PaperBagEtc	PaperBag	223	OtherChem	PhotoFilm	273	AlSecond	NonFerSecond
174	PaperBagEtc	DieCutPpr	224	OtherChem	MscChemProdW	274	FerrFoundry	FerrFoundry
175	PaperBagEtc	Envelopes	225	OtherChem	MscChemProdN	275	NonFeFondry	AlumFoundry
176	Stationery	Stationery	226	PlstPacking	PlstPacking	276	OthForgStmp	IronForging
177	SanitPpr	SanitPpr	227	PlstPipe	PlstPipe	277	OthForgStmp	NonForging
178	OthPprProd	OthPprProd	228	LamPlstPlate	LamPlstPlate	278	RollForming	RollForming
179	SuppPrint	BsnsForms	229	PlstBottle	PlstBottle	279	OthForgStmp	OthForgStmp
180	SuppPrint	BookPrntng	230	PlstPlumbing	ResFlooring	280	CutleryHndTl	Cutlery
181	SuppPrint	BlnkBook	231	PlstPlumbing	PlstPlumbing	281	CutleryHndTl	HandEdgeTool
182	Printing	Printing	232	FoamProduct	FoamProduct	282	CutleryHndTl	SawBlade
183	SuppPrint	Binding	233	Tires	Tires	283	CutleryHndTl	KitchenUtn
184	SuppPrint	PrepressSvc	234	RbrPlstHose	RbrPlstHose	284	PltWkFabMtl	PrefMtlBldg
185	PetrolRefiW	PetrolRefiW	235	OthRbrProd	OthRbrProd	285	PltWkFabMtl	FabStrctMtl
186	PetrolRefiN	PetrolRefiN	236	ClayProducts	VitChinPlb	286	PltWkFabMtl	PlateWork
187	AsphaltPave	AsphaltPave	237	ClayProducts	VitChinArtcl	287	PltWkFabMtl	MtlWndoDoor
188	AsphltShngW	AsphltShngW	238	ClayProducts	PorcElect	288	PltWkFabMtl	SheetMtl
189	AsphltShngN	AsphltShngN	239	ClayProducts	BrickClyTile	289	OrnArchMtl	OrnArchMtl
190	OthPetColPW	PetOilGreasW	240	ClayProducts	CeramTile	290	Boiler	Boiler
191	OthPetColPN	PetOilGreasN	241	ClayProducts	NonclayRefr	291	MetalTank	MetalTank
192	OthPetColPW	OthPetCoalW	242	ClayProducts	ClayRefrac	292	MetalCntnr	MetalCntnr
193	OthPetColPN	OthPetCoalN	243	GlassPrds	GlassCntnr	293	Hardware	Hardware
194	Petrochem	Petrochem	244	GlassPrds	OthGlassPrd	294	SprnWirePrd	SprnWirePrd
195	IndGasW	IndGasW	245	CementW	CementW	295	MachShops	MachShops
196	IndGasN	IndGasN	246	CementN	CementN	296	ScrewNut	ScrewNut
197	SynthDyeW	SynthDyeW	247	ReadyMix	ReadyMix	297	CoatEngvHeat	MtlHeatTrt
198	SynthDyeN	SynthDyeN	248	ConcrPipBlok	ConcrBlock	298	CoatEngvHeat	MtlCoatEngrv
199	OthInorgChmW	OthInorgChmW	249	ConcrPipBlok	ConcrPipe	299	CoatEngvHeat	ElcPlatAnod
200	OthInorgChmN	OthInorgChmN	250	OthConcPrd	OthConcPrd	300	MtlValve	MtlValve

Table 1.1: Mapping amended 406 to previous 554 sectors (3)

	Amend406	Prev554		Amend406	Prev554		Amend406	Prev554
301	BallBearng	BallBearng	351	FluidPowMach	FluidCylindr	401	MotorHome	MotorHome
302	AmmunitArms	SmallArms	352	FluidPowMach	FluidPump	402	TravlTrlr	TravlTrlr
303	AmmunitArms	OthOrdnance	353	OthGenPrpMac	Scales	403	VehiclPartsW	VehiclPartsW
304	FabPipeFtng	FabPipeFtng	354	Computers	Computers	404	VehiclPartsN	VehiclPartsN
305	MsFabMtlMfg	IndPattern	355	CmptrStorage	CmptrStorage	405	Aircraft	Aircraft
306	MsFabMtlMfg	EnamIronMtl	356	CmptTrmPerip	ComptrTermnl	406	AirEngines	AirEngines
307	MsFabMtlMfg	MsFabMtlMfg	357	CmptTrmPerip	OCptrPeriph	407	OthAirParts	OthAirParts
308	AmmunitArms	Ammunition	358	Telephone	Telephone	408	Missiles	Missiles
309	FarmMach	FarmMach	359	BroadcastEq	BroadcastEq	409	MissilPrts	MissilPrts
310	LawnEquip	LawnEquip	360	CommunEquip	CommunEquip	410	RlrdCars	RlrdCars
311	ConstMach	ConstMach	361	AudVidEquip	AudVidEquip	411	Ships	Ships
312	MiningMach	MiningMach	362	Circuit	ElectTube	412	Boats	Boats
313	MechPowEqp	OilGasMach	363	Semicondctr	Semicondctr	413	MotrBikes	MotrBikes
314	MechPowEqp	SawmillMach	364	OtElectrnic	OtElectrnic	414	ArmyTanks	ArmyTanks
315	MechPowEqp	PlstRbrMach	365	ElectroMedic	ElectroMedic	415	OthrTransEq	OthrTransEq
316	MechPowEqp	PaperMach	366	SearchNavig	SearchNavig	416	WoodKitcCabt	WoodKitcCabt
317	MechPowEqp	TxtlMach	367	EnviroContrl	EnviroContrl	417	UphlHldFurn	UphlHldFurn
318	OthGenPrpMac	PrintingMach	368	ProcVblInsts	ProcVblInsts	418	NonUpHhlFurn	NonUpHhlFurn
319	OthGenPrpMac	FoodMach	369	FluidMeters	FluidMeters	419	OthHhFurn	MtlHhFurn
320	SemicondMach	SemicondMach	370	ElecTestInst	ElecTestInst	420	InstFurn	InstFurn
321	OthIndMach	OthIndMach	371	LabInsts	LabInsts	421	OthHhFurn	OthInsHhFurn
322	OthGenPrpMac	OfficeMach	372	RadiationIns	RadiationIns	422	WoodOffcFurn	WoodOffcFurn
323	OptInstLens	OptInstLens	373	WatchClock	WatchClock	423	WoodOffcFurn	CustomWdwrk
324	PhotoEquip	PhotoEquip	374	RepMagOptMed	SoftwareRep	424	NonWdOffFurn	NonWdOffFurn
325	OSvcIndMach	OSvcIndMach	375	RepMagOptMed	AudVidReprod	425	ShcaseShlv	ShcaseShlv
326	OthGenPrpMac	VendingMach	376	RepMagOptMed	MagOptMedia	426	UphlHldFurn	Mattress
327	OthGenPrpMac	AirPurMach	377	Lightbulbs	Lightbulbs	427	UphlHldFurn	BlindShade
328	FanBlower	FanBlower	378	LightFxtr	LightFxtr	428	UphlHldFurn	LabAppFurn
329	HeatingEq	HeatingEq	379	ElecSmallApp	EleHswrFans	429	SrgMedInst	SrgMedInst
330	ACRefrig	ACRefrig	380	ElecSmallApp	HshldVacuum	430	SurgAppSupp	SurgAppSupp
331	OthGenPrpMac	MoldMfg	381	ElecLargeApp	HshldStove	431	DentalEquip	DentalEquip
332	CutRollMetwk	CuttingMach	382	ElecLargeApp	HshldFridge	432	Ophthalmic	Ophthalmic
333	CutRollMetwk	FormingMach	383	ElecLargeApp	HshldLaundry	433	DentalLab	DentalLab
334	ToolDieJig	ToolDieJig	384	ElecLargeApp	OthHshldApp	434	Jewelry	Jewelry
335	CutRollMetwk	ToolAccessry	385	PwrTrnsfrmr	PwrTrnsfrmr	435	SportGoods	SportGoods
336	CutRollMetwk	RollMillMach	386	MotorGenratr	MotorGenratr	436	Toys	Toys
337	Turbine	Turbine	387	Switchboard	Switchboard	437	OfficSupply	OfficSupply
338	OthEngEquip	OthEngEquip	388	Relays	Relays	438	Signs	Signs
339	SpeedChng	SpeedChng	389	StorBattery	StorBattery	439	VehiclParts	Gaskets
340	MeasDspPump	Pumps	390	PrimBatter	PrimBatter	440	OthWoodPrd	MusicInstr
341	AirGasCmprs	AirGasCmprs	391	WireOptCable	FibOptCable	441	OthWoodPrd	Brooms
342	MeasDspPump	MeasDspPump	392	WireOptCable	OtherWire	442	OthWoodPrd	Caskets
343	FluidPowMach	Elevators	393	WireDevice	WireDevice	443	MiscManuf	MiscManuf
344	FluidPowMach	Conveyors	394	CarbonProds	CarbonProds	444	WholesaleTr	WholesaleTr
345	FluidPowMach	Hoists	395	MsElEquip	MsElEquip	445	AirTrans	AirTrans
346	OthGenPrpMac	IndTrukTrac	396	AutomobilesW	AutomobilesW	446	RailTrans	RailTrans
347	PdrivnHandTl	PdrivnHandTl	397	AutomobilesN	AutomobilesN	447	WaterTrans	WaterTrans
348	MachineTool	WeldEquip	398	HeavyTruck	HeavyTruck	448	TruckTrans	TruckTrans
349	PackngMach	PackngMach	399	VehicleBody	VehicleBody	449	GrdPassTrans	GrdPassTrans
350	IndFurnace	IndFurnace	400	TruckTrailer	TruckTrailer	450	Pipeline	Pipeline

Table 1.1: Mapping amended 406 to previous 554 sectors (4)

	Amend406	Prev554		Amend406	Prev554		Amend406	Prev554
451	ScenSuppTran	ScenSuppTran	486	CmptTrmPerip	OthCptrSvce	521	AmuseServic	FitnessCtrs
452	PostalSvc	PostalSvc	487	MgmtCnsltSv	MgmtCnsltSv	522	AmuseServic	Bowling
453	Couriers	Couriers	488	EnvCnsltSvc	EnvCnsltSvc	523	AmuseServic	OthAmuseSvce
454	Warehousing	Warehousing	489	ResDevelSvc	ResDevelSvc	524	HotelsOthAcc	Hotels
455	RetailTr	RetailTr	490	Advertising	Advertising	525	HotelsOthAcc	OthAccomod
456	NewspaperPb	NewspaperPb	491	PhotoSvce	PhotoSvce	526	EatDrinkPlce	EatDrinkPlce
457	PerdclPub	PerdclPub	492	VetSvces	VetSvces	527	AutoRepWash	CarWashes
458	BookPub	BookPub	493	MscProfSvces	MscProfSvces	528	AutoRepWash	AutoRepair
459	DataPub	DataPub	494	CompanyMgmt	CompanyMgmt	529	ElEquiRepair	ElEquiRepair
460	SoftwrPub	SoftwrPub	495	OffAdmSvces	OffAdmSvces	530	MachinerRp	MachinerRp
461	MoviesVideo	MoviesVideo	496	FacilSupSvc	FacilSupSvc	531	HhGoodsRpr	HhGoodsRpr
462	SoundRecord	SoundRecord	497	EmplSvce	EmplSvce	532	PersCareSvce	PersCareSvce
463	RadioTV	RadioTV	498	BusnsSupSvc	BusnsSupSvc	533	DeathCareSv	DeathCareSv
464	SatelTlCable	CableNetwrks	499	TravelSvce	TravelSvce	534	CleanLaundry	CleanLaundry
465	TelecWireles	Telecomm	500	DetectivSvce	DetectivSvce	535	OthPerSvce	OthPerSvce
466	WebLibrInfo	InfoSvce	501	BldgSvce	BldgSvce	536	ReligiousOrg	ReligiousOrg
467	DataProcSvc	DataProcScv	502	OthSuppSvce	OthSuppSvce	537	GrantOrg	GrantOrg
468	NonDepCredit	NonDepCredit	503	WastServW	WastServW	538	CivSocialOr	CivSocialOr
469	Securities	Securities	504	WastServN	WastServN	539	PrivHhlds	PrivHhlds
470	InsCarriers	InsCarriers	505	NonComImp	NonComImp	540	OthFedGEnt	OthFedGEnt
471	InsBrokers	InsBrokers	506	EleSecSchool	EleSecSchool	541	OthSLGEnt	OthSLGEnt
472	FundsTrusts	FundsTrusts	507	Colleges	Colleges	542	SLGEduc	SLGEduc
473	MonetDepCred	MonetDepCred	508	OtherEducSv	OtherEducSv	543	NonDefG	GenGovInd
474	RealEstate	RealEstate	509	HomeHlthSvc	HomeHlthSvc	544	OwnOccDwell	OwnOccDwell
475	AutoRental	AutoRental	510	MedOffices	MedOffices	545	NatlDefG	NatlDefG
476	GenrlRentl	VideoRental	511	AmbHlthSvce	AmbHlthSvce	546	NonDefG	NonDefG
477	MachEquRntl	MachEquRntl	512	Hospitals	Hospitals	547	SLGOther	SLGOther
478	GenrlRentl	GenrlRentl	513	NursingFcil	NursingFcil	548	Holiday	Holiday
479	AssetLessors	AssetLessors	514	ChildCare	ChildCare	549	FgnHol	FgnHol
480	LegalSvces	LegalSvces	515	SocialSvce	SocialSvce	550	ExpTour	ExpTour
481	Accounting	Accounting	516	PerfArts	PerfArts	551	ExpEdu	ExpEdu
482	ArchEngSvce	ArchEngSvce	517	SpectSports	SpectSports	552	OthNonRes	OthNonRes
483	DesignSvce	DesignSvce	518	IndArtists	IndArtists	553	WT_EXP	WT_EXP
484	CustCptrProg	CustCptrProg	519	Promoters	Promoters	554	AT_EXP	AT_EXP
485	cptrSysDesgn	cptrSysDesgn	520	MuseumZoo	MuseumZoo			

1.3 Comparing the previous and amended databases

The key contribution of the 2017 supply-use tables to the update is to impose updated cost and sales structures on the 2019 database. A program compares matrices of the 2017 USE table and the updated 2019 USE matrix (i.e., basic transactions plus margins). This revealed the need to scale the USE matrix to reflect altered technologies over time. National accounts updates are confined to rescaling activities at broad sector levels. Rescaling of the database at a more disaggregated level proceeds using information from the 2017 table.

A notable exception concerns farm outputs. Since the BEA use table does not represent farm activities by commodities, any rescaling of farm outputs is undertaken using national accounts data.

After imposing revised cost and sales structures at a disaggregated level, 2019 national accounts provide target levels for the database.

1.4 Preparing a database for agricultural and food scenarios

The revised 2019 national database includes 406 sectors, including those divided into water transport using (e.g., CornW) and non-using (e.g., CornN). An early step in devising an agrifood master database is to aggregate from 406 sectors to 191 sectors. This arises from the need to keep the dimensions of the master database manageable. Table 1.2 shows the effect of successive aggregations on sectoral detail. Columns (1) and (2) summarise the mapping shown in table 1.1 from 554 to 406 sectors. The aggregation to 406 sectors is concentrated in the food & drinks group and other manufactures group.

Table 1.2: Broad sector representation in various CGE databases

	Original (1)	Updated (2)	AgriFood version (3)	AgriFood master (4)
Broad group	Sectors per broad group			
Agriculture	36	36	36	31
ForFishHunt	5	2	1	1
Mining	17	13	11	7
Utilities	9	9	9	9
Construction	13	3	3	3
Food & drinks	49	33	29	24
Other manufactures	316	207	60	56
Transport	10	10	9	9
Health & social services	7	7	7	7
Education	4	3	1	1
Financial services	6	6	1	1
Media & publishing	10	10	4	4
Business & support services	10	9	3	3
Professional services	15	14	3	3
Other services	48	44	14	13
Total	554	406	191	172

The only aggregation of agricultural sectors entails recombining of sectors such as corn split into water transport using and non-using. Once different technologies are in the 191 sector regional database for different regions, we can aggregate these sectors. Corn, wheat and other water transport using sectors in the Mississippi Basin regions will have different technologies than the same sectors outside the basin, following the aggregation to 172 sectors. Most of the aggregation from 406 sectors to 191 and then 172 sectors occurs in manufacturing. This reflects the emphasis in the agriculture and food master database on food processing rather than other manufactures.

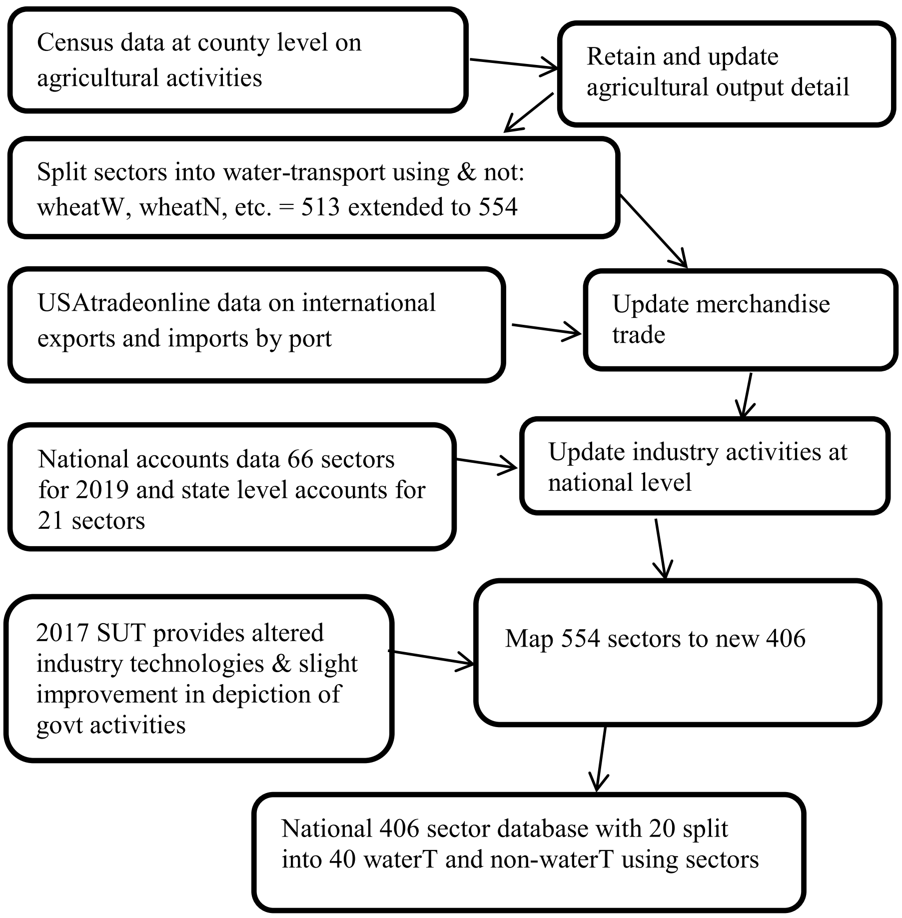
Nevertheless, the new BEA supply-use tables necessitate some aggregation of food & drinks sectors from the existing sectors, including the milk and butter example noted previously. Unlike farm outputs, for which agricultural census data are available at a detailed sectoral level, there are no detailed data to update and regionalize the original food & drinks sectors. Table 1.3 shows the detailed aggregation of food & drinks (an excerpt of table 1.1).

Table 1.3: Food & drinks aggregation from (1) to (2)

(1)	(2)	(1)	(2)	(1)	(2)
FlourMillW	FlourMaltW	ConfNonchoc	SugarManufN	PrepDough	BakingProds
FlourMillN	FlourMaltN	Milk	MilkButter	Pasta	CookiPastTrt
RiceMill	FlourMaltN	Butter	MilkButter	Tortilla	CookiPastTrt
Malt	FlourMaltN	AnSlauXPlt	MeatProds	NutsPnutBtr	SnackFood
SoyProcW	SoyOthProc	Meat	MeatProds	OthSnack	SnackFood
SoyProcN	SoyOthProc	RendByprod	MeatProds	MayoDrsng	SeasDrsng
OthOilseed	SoyOthProc	FrozCake	BakingProds	Spices	SeasDrsng
ConfCacao	SugarManufN	Bread	BakingProds		
ConfChoc	SugarManufN	Cookies	CookiPastTrt		

As shown in column (3) of table 1.2, the agrifood version of the national database includes 191 sectors. The split between water transport using and non-using sectors remains in the database until the multi-regional master database is generated, giving the eventual 172 sectors.

Figure 1.1: Summary of national database and regional activities update



1.5 Regional share estimates

Wittwer (2017a) details the use of 2010 census data to estimate regional activity shares across the sectors of the earlier USAGE-TERM database. Employment data in the 2010 census were available for four digit NAICS sectors at the county level. From this, the older USAGE-TERM database includes a county level top-down module of activities. The available 2020 census data are not as detailed as for 2010, being confined at present to two-digit NAICS. Agricultural census data for 2017 are used to update agricultural sector county activities. The regional update is not independent of the national update. This is because regional activities are necessary for the split of the national database into water transport using and non-using commodities as shown near the top of figure 1.1.

US Energy Information Administration provide updated coal mining data by county.[3] Electricity generation data by type of generation and county is based on the Global Power Plant Database.[4]

BEA provide estimates of GDP at the county level for 2019.[5] These estimates are used to revise county-level activities, particularly for OwnOccDwell (covering imputed plus actual housing rentals). Mining activities provide outliers. For example, Loving County, Texas, with a 2019 population of 182 and over 300 oil wells has GDP of $4.76 bn or $26 million per capita as estimated by BEA. Much of the income earned in Loving County would accrue to domestic and foreign shareholders. GDP in this extreme case has been scaled down in further database processing to $561 million. This is still excessive, implying $3 million of GDP per capita. However, the objective is to obtain reasonable agricultural district estimates of economic activity. Once Loving County and other outliers are aggregated to the district level, the economic activity estimates are defensible.

A subsequent data program scales county data by state so as to align with 21 sector state accounts data for 2019. The required regional shares data are production (R001), industry investment (R002), household consumption (R003), international exports (R004), government consumption (R005) and import shares (MShr). We assume that industry investment shares equal production shares (i.e. R002(i,d)=R001(i,d) for industry i in region d).

Estimating household expenditures by small regions entails several steps. First, labour income is estimated from primary factor incomes by industry. The assumption is that household expenditures at the regional level are tied to labour income rather than GDP. Regional levels for the housing (imputed and actual) rental sector OwnOccDwell are based on regional labour income. Small regional populations also provide a guide concerning appropriate shares.

Household expenditures on water transport were altered to capture differences between the Mississippi Valley states and elsewhere. The adjustment was not binary, but rather made within-valley water transport expenditures higher than elsewhere.

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[3] Downloaded from www.eia.gov/coal/data.cfm

[4] Downloaded from https://github.com/wri/global-power-plant-database

[5] Downloaded from https://www.bea.gov/news/2022/gross-domestic-product-county-2021

Online international trade data (https://usatrade.census.gov/) by port are the source of international trade shares (R004 and MShr) for merchandise commodities. Non-merchandise imports do not require ports. Import values for this sectoral subset are calculated using primary factor shares for intermediate and investment imports and household shares for private household and public expenditures.

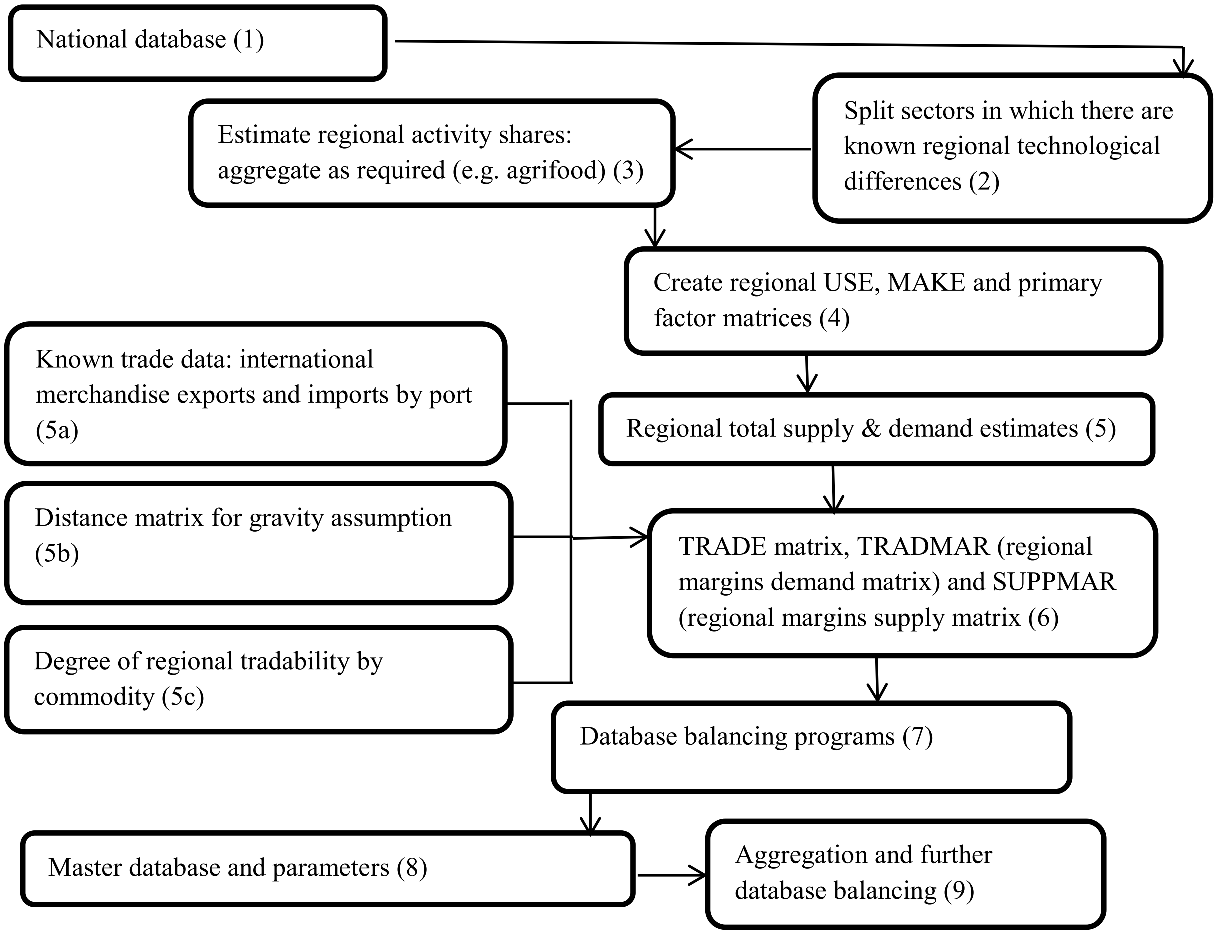
Government consumption shares by default are set equal to household expenditure shares (i.e., R005(c,d)=R003(c,d) for commodity c in region d). In the case of both household and government consumption, we can supplement existing share estimates if better data are available. For example, BEA provide some state level household expenditure estimates to which we could scale initial spending values by region (see https://www.bea.gov/data/consumer-spending/state).

For convenience, regional activities are stored as values rather than shares so that simple aggregations only are required when sectors are aggregated to the master database sectoral level. For example, at the maximum level of disaggregation, regional coal value-added is set equal to R001(i,d) multiplied by coal value-added from the national CGE database.

1.6 Preparing a master database based on agricultural districts

Figure 1.2 provides a summary of regional master database generation procedure. Sections 1.2 to 1.4 cover steps (1) and (2). Section 1.5 covers step (3).

Figure 1.2: Summary of USAGE-TERM database generation



The national database is split into regions using regional activity shares, thereby creating regional USE, MAKE and primary factor matrices (step (4)). In a bottom-up multi-regional CGE database, we need to link the regions using inter-regional trade matrices. To create the trade matrices, we use a combination of known data and defensible assumptions (steps 5a, 5b and 5c). International trade data by port for merchandise commodities are available. Beyond this, we use further assumptions. One is the gravity assumption, in which regional demands in a given region are inversely proportional to the distance from regional suppliers. The other is that some commodities are relatively non-traded. These include housing, elementary schooling and other relatively local services.

A matrix of distances between regions is required to utilize the gravity assumption. Latitude and longitude coordinates for the regions of the database enable us to devise a distance matrix. These are available from Shapemap files of agricultural districts.[6] The TRADE and TRADMAR (i.e., demand for margins associated with each TRADE element) matrices generated in step (6) combine information on known regional supplies and demands, known international merchandise trade and assumptions concerning the degree of tradability. For example, a region that specializes in a particular commodity with a large proportion of sales to other regions may still import some of that commodity from elsewhere. That is, the gravity assumption allocate trades based on total supplies and total demands, not being confined to distributing excess supplies and excess demands. Horridge (2012) details the TERM database methodology. This methodology is rapid and reproducible.

Following the creation of initial matrices, a RAS-based program enforces various identities. The import slice of the TRADE matrix must equal imports on the USE side of the database. For the margins subset of commodities, the MAKE matrix summed across industries must equal the domestic TRADE slice plus margins supply SUPPMAR. Other identities enforced concern the supply of and demand for margins (step (7)).

Finally, the database is aggregated for a specific application, so that it has dimensions suitable for running a CGE model. A database balancing program TERMSCAL, which operates on TERM-style databases, ensures that the aggregated database obeys all identities.

Navigating the USAGE-TERM database

Figure 1.3 is a representation of the USAGE- TERM database. We start by describing the arrays that run down the LHS of figure 1.3. The USE matrix includes the value of transactions for each commodity at basic prices plus margins. The TAX matrix includes commodity taxes on corresponding transactions. USE and TAX have dimensions COM (*c*) x SRC (*s*) x USER (*u*) x DST (*d*). COM refers to commodities, USER to intermediate (industries) and final users and DST to destination regions. The dimension SRC includes domestic ("dom") and imported ("imp") sources.

Final users for USE and TAX include households (HOU), investment (INV), government (GOV) and exports (EXP). The set USER includes intermediate users IND plus final users. The two satellite matrices shown at the top of figure 1.3 are HOUPUR and INVEST. HOUPUR includes provision for multiple households, with dimensions COM x HOU x DST. INVEST provides the commodity composition of investment, expanding from the commodity

[6] Shapemap files were downloaded from https://cartographyvectors.com/map/1294-usda-agricultural-districts. Dean Mustakinov of the Centre of Policy Studies coordinated the translation of Shapemap to Shademap files; the Shademap software is available at https://www.copsmodels.com/shademap.htm.

dimension in the USE and TAX matrices to include industries. INVEST enables the practitioner to distinguish between different types of investment. Livestock sectors, for example, require some own-inputs to adjust herd levels. Similarly, the education sector requires own-inputs to maintain the training capacity of the sector. We expect the shares of education inputs in total investment to differ between the livestock and education industries, just as the livestock input shares to livestock and education should differ.

In showing the identities linking the satellite matrices for household consumption and investment to the USE and TAX matrices, we introduce PUR, depicting transactions for all Users u at purchasers' prices and source-composite PUR_S:

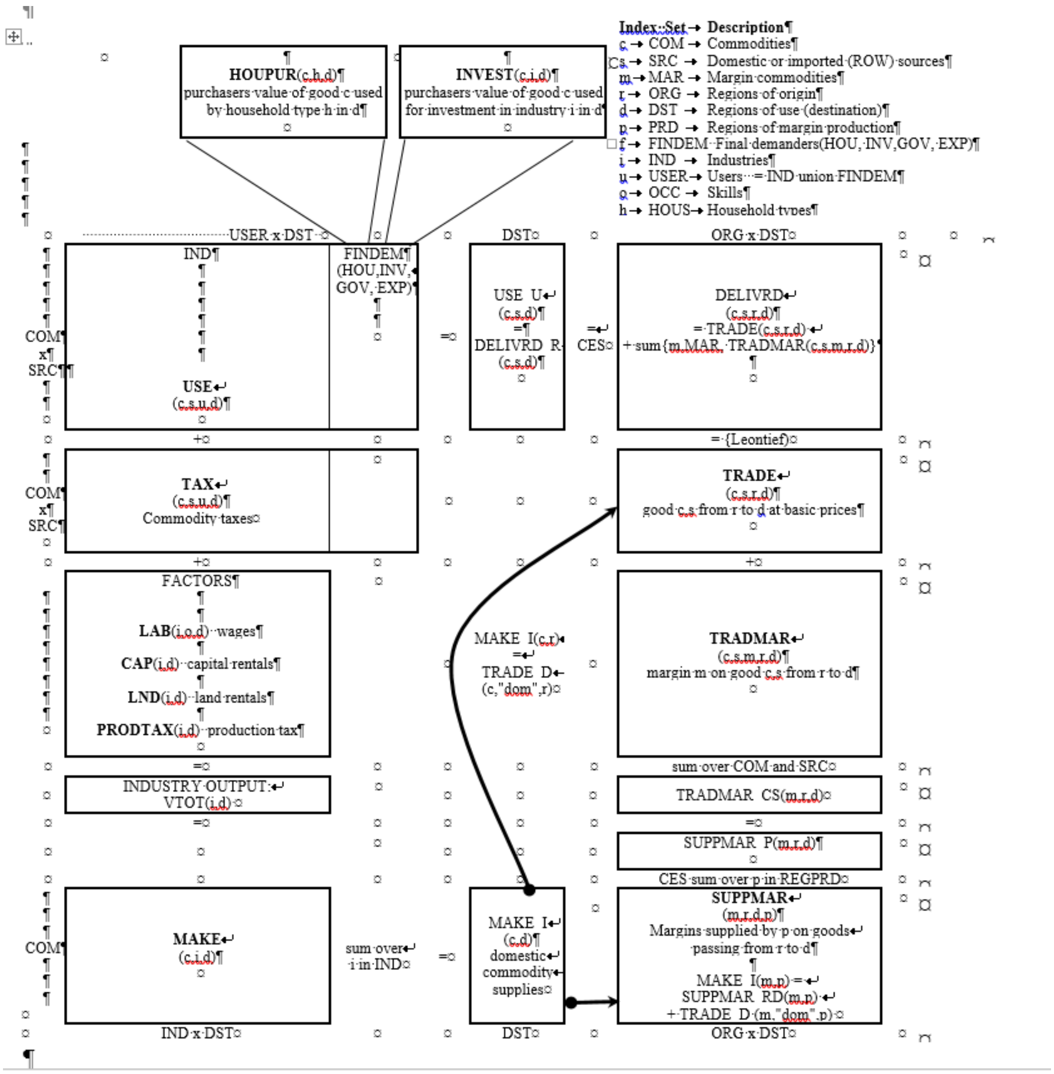
```
PUR(c,s,u,d)=USE(c,s,u,d) + TAX(c,s,u,d)                (1.1)

        PUR_S(c,u,d)=sum{s,SRC,PUR(c,s,u,d)}            (1.2)

PUR_S(c,"Hou",d)= sum{h,Hou,HOUPUR(c,h,d)}              (1.3)

PUR_S(c,"Inv",d)= sum{i,IND,INVEST(c,i,d)}              (1.4)
```

Figure 1.3: USAGE-TERM flows



Source: Horridge (2012).

Figure 1.3, below the TAX matrix on the LHS, shows primary factor inputs labour (LAB), capital (CAP), land (LND) and production taxes (PRODTAX). Each of these excepting labour has the dimension IND x DST. Labour has dimensions IND x OCC x DST, where OCC refers to occupational type. Production taxes differ from commodity taxes in that they are based on industry outputs, whereas commodity taxes are based on use, in the case of industries, as intermediate inputs.

The total costs of industry production, VTOT, are equal to the sum of intermediate inputs (PUR) and primary inputs:

```
VTOT(i,d)= sum{c,COM,sum{s,SRC,PUR(c,i,d)}} +sum{o,Occ,LAB(i,o,d)}
        + CAP(i,d)+ LND(i,d)+ PROXTAX(i,d)                          (1.5)
```

The MAKE matrix shows the commodity outputs of each industry. Statistical agencies usually prepare MAKE data based on industry surveys. Typically, industries produce many outputs. For example, a wholesaling grocery firm may undertake some food processing. For the purposes of CGE modelling, our usual preference is to diagonalise the MAKE matrix so that each industry produces a unique commodity which has the same name.[7] Exceptions to this practice include Dixon *et al*. (2011), in which separate dry-land and irrigated technologies produce identical agricultural commodities. Industry costs equal MAKE outputs summed across commodities:

```
VTOT(i,d)= sum{c,COM,MAKE(c,i,d)                                    (1.6)
```

The links between the LHS and RHS of figure 1.3 concern theoretical elaborations to reduce a multi-regional model to manageable dimensions. TERM relies on sourcing assumptions that reduce the size of the overall database, but increase the number of market clearing identities. Consider a USE matrix that includes domestic origins, unlike that in TERM. A 50 sector, 20 region USE matrix would have dimensions COM x SRC x USER x ORG x DST, a total of 2.16 million cells (=50x2x54x20x20). ORG denotes the region of origin. In TERM, the corresponding USE matrix (COM x SRC x USER x DST) without details of origin has 0.108 million cells (=50x2x54x20) and the accompanying TRADE matrix of dimensions COM x SRC x ORG x DST, without user details, has 0.04 million cells (=50x2x20x20). The TERM configuration uses two matrices with a total of 0.148 million cells, reducing the database size by almost 15-fold. The diagonal of TRADE (r=d) shows the value of local usage which is sourced locally. For foreign merchandise (s="imp") the regional source subscript r (in ORG) for merchandise commodities denotes the port of entry. In the case of imported services, such as a purchase of electronic data, the import is assigned directly to the region of use, appearing as a diagonal element in the imported slice of the TRADE matrix.

The TRADMAR matrix shows the accompanying margins (m in MAR) for each cell of the TRADE matrix. DELIVRD is the sum of TRADE and TRADMAR, the delivered (basic + margins) value of all flows of goods within and between regions. TRADMAR does not identify where a margin flow is produced. In the middle of figure 1.3 near the top, we see the identity that links the TRADE, which is a component of DELIVRD, and USE matrices (equation 1.8).

```
USE_U(c,s,d) =sum{i,IND, USE(c,s,i,d)} +USE(c,s,"hou",d) +USE(c,s,"inv",d)+
                   USE(c,s,"gov",d) +USE(c,s,"exp",d)                 (1.7)

USE_U(c,s,d)=DELIVRD_R(c,s,d)                                       (1.8)
```

Each matrix needs to be summed across the dimension missing from the other. Therefore,

[7] The archive item https://www.copsmodels.com/archivep.htm TPMH0062 includes programs to diagonalise a MAKE matrix and modify the accompanying CGE database.

TRADE is summed across ORG and USE is summed across USER. This implies that all users source a given commodity from all origins in common proportions. The TERM strategy to deal with known cases where the common-sourcing assumption may break down is to disaggregate further in the sectoral dimension COM, as has been done to assign water-transport using regions to some commodities.[8]

Matrix SUPPMAR shows where margins are produced (p in PRD). It lacks the commodity-specific subscripts c (COM) and s (SRC): this indicates that, for all usage of margin good m used to transport any goods from region r to region d, the same proportion of m is produced in region p. The demand-side TRADMAR, in addition to excluding users, excludes the origin of margins. The missing dimensions in the respective supply and demand margins matrices keep each of them to a manageable size. The identity linking supply and demand of margins require summing across the dimensions missing from the other side:

```
SUPPMAR_P(m,r,d)= Sum{p,PRD, SUPPMAR (m,r,d,p)}                (1.9)
TRADMAR_CS(m,r,d) = Sum{c,COM,sum{s,SRC,TRADMAR_CS(m,r,d}}     (1.10)
TRADMAR_CS(m,r,d) = SUPPMAR_P(m,r,d)                           (1.11)
```

TRADE summed over all destinations (TRADE_D) should equal supply (MAKE_I) for the non-margins c subset of domestically-produced commodities.

```
MAKE_I(c,r)=TRADE_D(c,"dom",r)                                 (1.12)
```

The identity for margins supply and demand requires an additional term, covering margins to facilitate trade flows. For the margins m subset of commodities, total demands equal direct demands TRADE_D("dom") plus margins demand SUPPMAR_RD, the sum of margins demanded over regional sources r and regional destinations d:

```
MAKE_I(m,r)=TRADE_D(m,"dom",r)+ SUPPMAR_RD(m,r)                (1.13)
```

Figure 1.4 shows the use, tax and factor inputs in the TERM model, but excludes the trade side of the database. In a single-country model such as ORANI (Dixon et al., 1982), this illustration covers virtually all flows. Trades with the rest of the world appear in the export column and in the imported slice of USE.

[8] Horridge (2011), Wittwer and Horridge (2010) and Wittwer and Horridge (2018) detail the theory of TERM.

Figure 1.4: TERM-style model excluding trades

		Absorption Matrix				
		Producers	Investors	Household	Export	Government
	Size	← I →	← I →	← 1 →	← 1 →	← 1 →
Basic + margin flows	↑ C×S ↓	USE(Ind)	USE(“Inv”)	USE(“Hou”)	USE(“Exp”)	USE(“Exp”)
Taxes	↑ C×S ↓	TAX(Ind)	TAX(“Inv”)	TAX(“Hou”)	TAX(“Exp”)	TAX(“Exp”)
Labour	↑ O ↓	LAB				
Capital	↑ 1 ↓	CAP				
Land	↑ 1 ↓	LND				
Production tax	↑ 1 ↓	PTX				

C = Number of Commodities
I = Number of Industries

S = 2: Domestic,Imported,
O = Number of Occupation Types

The agrifood database

The initial master database generated by the TERM procedure covers 191 sectors in 347 regions. These regions include 321 USDA agricultural regions plus 26 non-agricultural region. The latter includes counties in a given state in which there is no agricultural activity recorded in farm census data.

Recall from table 1.2 that 191 sectors are aggregated to 172. This is because sectors divided into water transport using and non-using can now be aggregated, as regional differences are depicted in the TERM procedure. Water transport is an example of a margin, which are the value of services used in delivery of goods to users. Margin supplies are separate from the supply of goods delivered to users. For example, if the producer price of wheat increases by 50%, but the producer value accounts for only 70% of the user price and margins prices remain unchanged, then the user price will increase by 35%, not 50%. Other margins include wholesale trade, retail trade, truck transport, rail transport, air transport and pipelines. In the 172 sector database, using wheat as an example, water transport as a share of total margins usage ranges from around 6% in the Mississippi Valley states to a negligible share elsewhere.

The theory of USAGE-TERM

USAGE-TERM follows the theory of TERM models, detailed in Wittwer and Horridge (2018).

1.7 General comments on master database size limitations

The largest master database created using the TERM methodology is for Australia. The most recent Australian database includes 216 sectors, 334 regions and 13 margins. Within GEMPACK software, this results in a master database of 3059 megabytes. The 191 sector, 347 region, 7 margin 2019 USAGE-TERM master database is 2646 megabytes, and the 172 sector version in which some sectors are no longer split to deal with water transport is 2458 megabytes. It may be computationally possible to generate a somewhat larger master database, but viewing it and aggregating it would be unnecessarily cumbersome.

How much larger would a master database be that contains 405 sectors, 3140 county regions and 7 margins? If it were possible to generate, view and aggregate, and certainly, a database in the TERM format would not be optimal to manage, it would contain 288 times the number of database cells of the largest Australian master database produced.

A master database containing 150 sectors, 460 regions and 7 margins would be approximately the same size as the largest Australian master database. Extending the number of sectors to 170 and reducing regions to 450 with 7 margins would result in a similarly sized database. In future studies with an urban focus, this would enable the user to depict metropolitan areas in some detail, with aggregation of agriculture, mining and manufactures, while aiming to preserve detail in service and utility sectors. The calculation used to predict the database size, which is only approximate given the evolving capabilities of GEMPACK in dealing with sparse matrices, is based on an archive item downloadable at https://www.copsmodels.com/archivep.htm (item TPGW0142).

1.8 The dynamic aggregator for USAGE-TERM

Preparing an aggregation of USAGE-TERM for dynamic scenarios requires three broad tasks. First, database values require a simple aggregation. Second, database parameters and baseline period-to-period shocks require weighted aggregation. Third, to ensure dynamic stability, investment to capital rental ratios, capital growth and rates of return are adjusted to be within reasonable bounds. Chapter 9 of Wittwer (2017a) provides an overview of the first and second tasks.

Concerning the first and second tasks, Mark Horridge devised the AGGHAR program more than 20 years ago to deal with simple and weighted aggregation. A TABLO-generated program prepares aggregation instructions based on an input file containing sectoral and regional mapping for the specific aggregation (https://www.copsmodels.com/archivep.htm item TPMH0187 contains an example, prepare.tab). The program prepares weights for aggregating parameters and is adapted in the case of dynamic aggregations to prepare baseline shocks.

The model code of USAGE-TERM and closure files have been modified to manage subsets within the dynamic aggregation. For example, within the master database, a subset of industries are assigned as either endogenous or exogenous investment sectors. Candidates for the latter include government-related services and utilities. Exogenous investment sectors in the master database are assigned a value of 1. Subsets are inferred after aggregation using the aggregated values. For example, if an aggregated sector has a marker exceeding 0.5, it is assigned as an exogenous investment sector. The need for exogenous investment sectors, excepting those with zero capital stocks, is probably unnecessarily as long as initial conditions for each industry, discussed next, are within reasonable bounds.

Dynamic stability is important in running CGE models and interpreting results. The practitioner uses imperfect and incomplete data to devise a multi-regional CGE database. Data on investment and capital rentals have certain features. For a start, investment is usually the most volatile component of the macroeconomic accounts. Capital rentals or GOS are also highly variable. An individual business or industry may suffer periodic years of negative GOS. This is particularly so in the farmer sector, in which a drought may result in a collapse in productivity and have severe impacts on rentals. CGE modelling is based on typical year data. For example, we would avoid using a database faithfully compiled at the depths of the GFC or during COVID lockdowns. It follows that some regularity needs to be enforced on rates of return and investment.

There is limited virtue in practitioners searching for data on the value of capital stocks. These may provide some perspective on industry-level investment. But investment is usually presented in the commodity dimension, though it typically distinguishes between private investment and various forms of public investment. It follows that adjusting industry-level investment to align better with capital rentals is unlikely to conflict with available data.

Within the national 2019 US CGE database, based on national accounts and a recent BEA USE table, annual investment is equal to approximately two-thirds of capital rentals. A program in the dynamic aggregation procedure for USAGE-TERM evaluates investment-to-capital rental ratios. It removes outliers at either extreme. For example, in the present program, all industries have annual investment equal to at least half of capital rentals.

Next, a revised investment matrix is imposed on the aggregated database. In theory it is possible to alter industry level investment without disrupting database balance, provided overall regional investment sales by commodity do not alter. This is because investment is not included in industry costs. Nevertheless, the database is rebalanced at this point as there may be minor imbalances in the master database.

A program calculates capital values as being equal to capital rentals divided by a target rate of return net of depreciation. A subsequent program checks that capital growth is within defined bounds. For outliers, capital stocks are adjusted to bring capital growth to the nearest bound. If a subsequent check reveals rate of return in a particular industry outside of defined rate-of-return bounds, capital stocks are adjusted again. This task is relatively straightforward provided investment to capital rental ratios are adjusted first. It bears repeating that this ratio adjustment almost certainly will not conflict with available investment data. It is more practical for a practitioner to treat extreme circumstances such as a collapse in investment as a scenario rather than part of initial conditions.

2. An application of the Agricultural District of USAGE-TERM to a hypothetical FMD outbreak

This scenario concerns a hypothetical outbreak of foot and mouth disease in Cedar County, East Central Iowa. This county was at the centre of the Iowa Cow War in 1931, arising from an outbreak of bovine tuberculosis.[9] The scenario is based on a hypothetical Australian example (Wittwer 2023). Ideally, any hypothetical scenario should include epidemiological input to ensure that the timeline and spread of disease is realistic. A scenario should also reflect state and federal government protocols to follow in the event of an outbreak.

Given the timeline of the hypothetical event, a quarterly version of dynamic USAGE-TERM has been prepared. A quarterly model requires several modifications from an annual model. In the equation linking investment and capital, quarterly investment values and quarterly depreciation rates are used instead of annual values and rates. In the equation linking the balance of trade and net foreign liabilities, a quarterly interest rate applies. Baseline shocks such as GDP growth are now quarterly rather than annual shocks. There is no need to create a new quarterly database, as annual investment provided by the usual database is divided by 4 in the modified model, so that quarterly investment enters the capital accumulation equation.

The outbreak occurs on a property in Cedar County, within the agricultural district of East Central Iowa. A quarantine region is declared within a three mile radius of the farm on which the outbreak was detected. A statewide quarantine measure, a standstill at saleyards and other livestock facilities, lasts for three days.[10]

The costs of the livestock standstill may be in tens of millions. Livestock within a three mile radius are vaccinated to die. Vaccinations costs are around $10 per head. 25,000 livestock are destroyed out of a district population of 5 million livestock.

The biggest single contribution to economic losses is in the form of trade sanctions on US dairy and meat products. The assumption, given the usual behavior of international trade partners, is that partners enact trade sanctions on US meat and dairy products, regardless of the port of exit. Given these trade sanctions, meat and dairy processors temporarily reduce their operating capacity. Within USAGE-TERM, these reductions are depicted by ascribing capital productivity losses that are related to the export share of total sales. Livestock investment in all of Iowa falls by 60% relative to base and remains so until trade sanctions are lifted.

The assumption is that Iowa is declared free of foot and mouth disease by the end of the second quarter. In this scenario, trading partners lift sanctions in the third quarter, with the consequence that baseline export demands are fully restored in the fourth quarter.

Labour market impacts of the scenario are shown in figures 2.1 to 2.4, for East Central Iowa, Rest of Iowa, Rest of Mid-West and Rest of USA respectively. Although the outbreak occurs in East Central Iowa, the harmful economic impacts in proportional terms are larger in the Rest of Iowa. This is because beef cattle and hogs account for a larger share of GDP in the latter. Although there is severe damage in terms of destroyed livestock on farms within a

[9] See https://history.iowa.gov/history/education/educator-resources/primary-source-sets/protest-america/iowa-national-guard-members
[10] These follow Australian protocols.

three mile radius of the detected outbreak, most of the economic damage arises from trade sanctions by importers on US livestock products.

Within USAGE-TERM, as the labour market weakens in a region, real wages adjust downward sluggishly. Therefore, in the quarter of the outbreak, most adjustment occurs via a reduction in employment rather than a fall in real wages. The main difference between the first and second quarters is that there is a small amount of international exports of animal products in the first, with an almost complete cessation in the second. Therefore, economic conditions are worse in the second quarter but because real wages fall further relative to base, employment does not drop further relative to base.

In the quarter of the outbreak, East Central Iowa's employment falls around 0.1% or 460 full-time equivalent (FTE) jobs below base, compared with 0.28% or 3950 FTE jobs in the Rest of Iowa, 0.02% or 5550 jobs in the Rest of the Mid-West and almost 0.01% or 12300 jobs in the Rest of USA.

Figure 2.1: Labour market in East Central Iowa (% deviation from base)

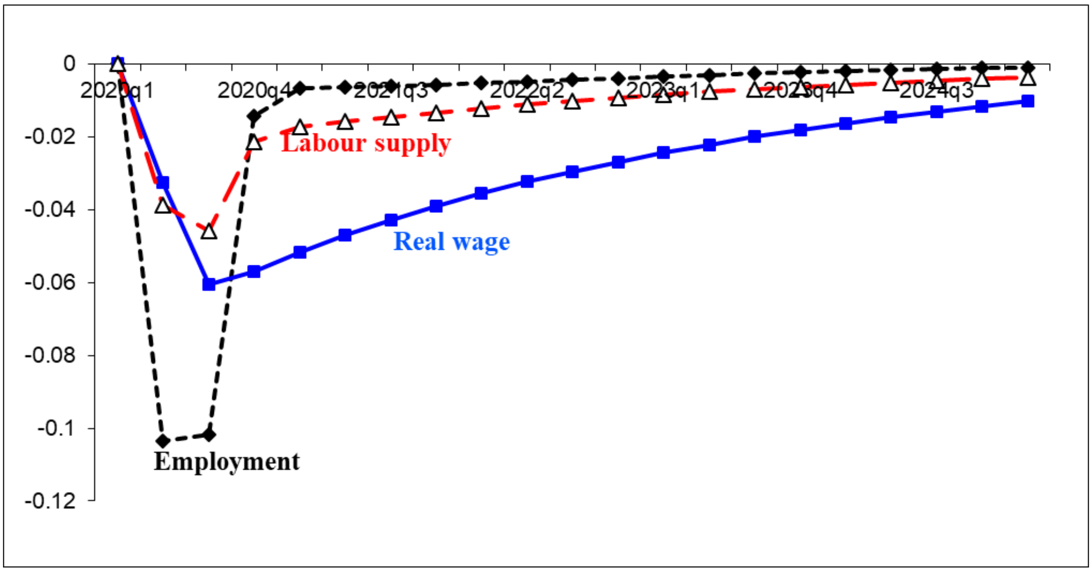


Figure 2.2: Labour market in Rest of Iowa (% deviation from base)

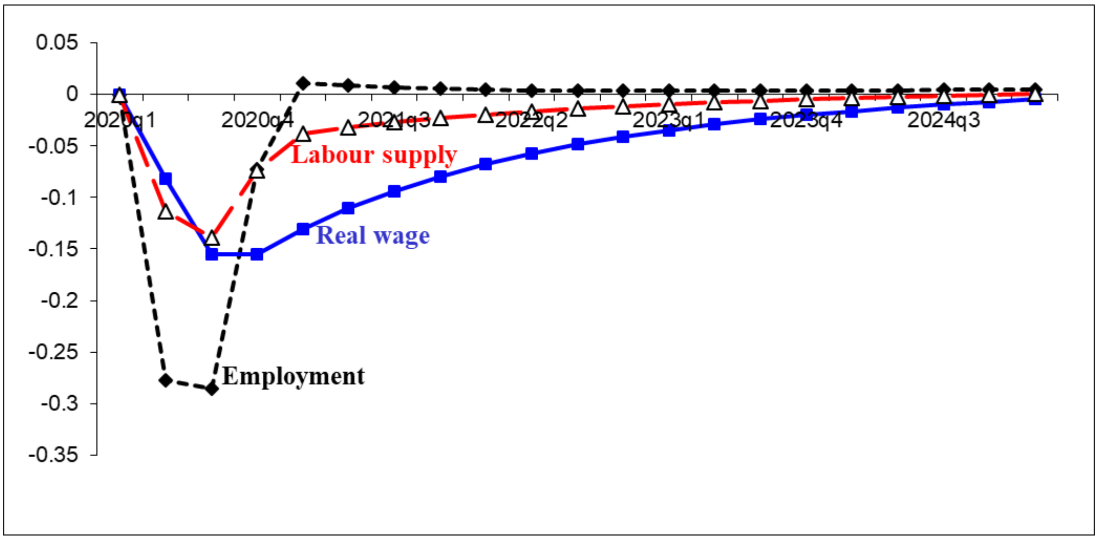


Figure 2.3: Labour market in Rest of Mid-West (% deviation from base)

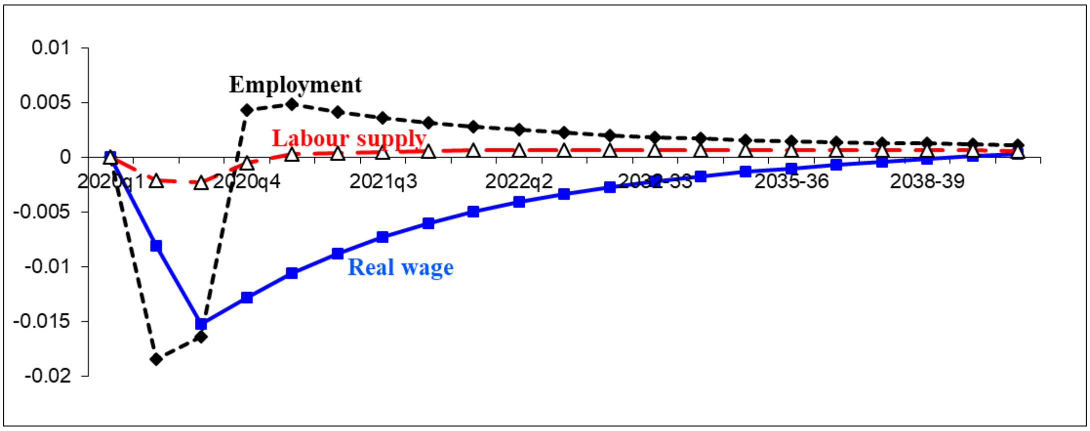


Figure 2.4: Labour market in Rest of USA (% deviation from base)

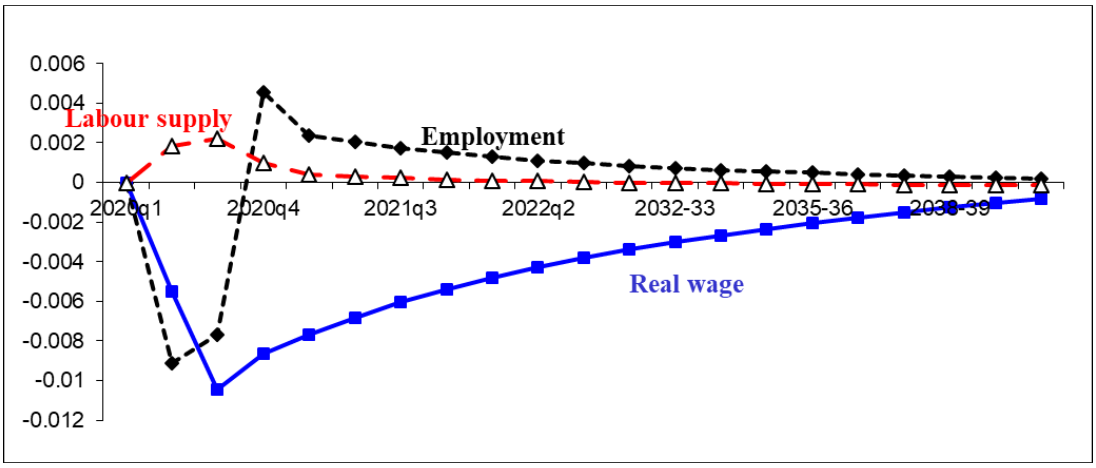
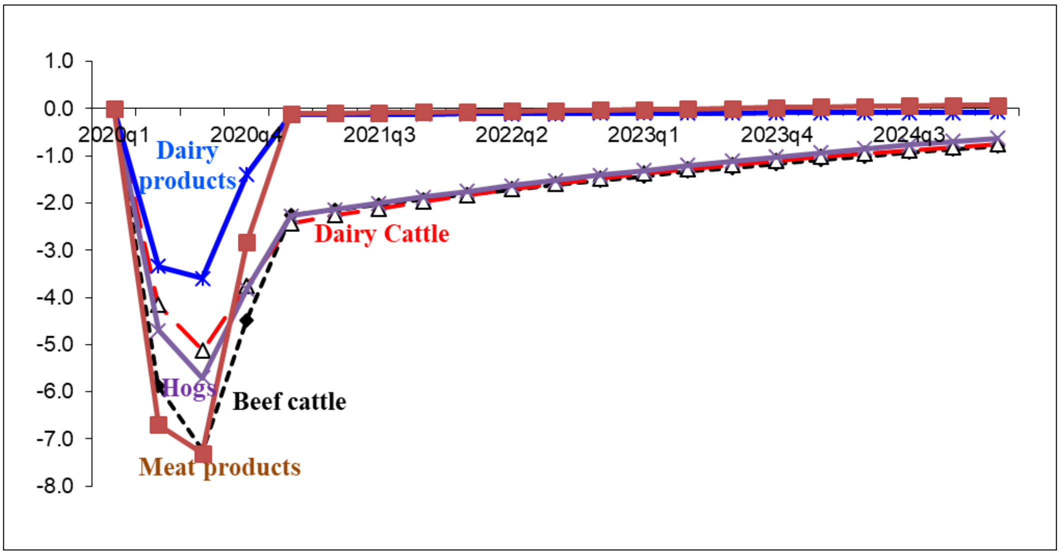


Figure 2.5: Industry outputs in East Central Iowa (% deviation from base)

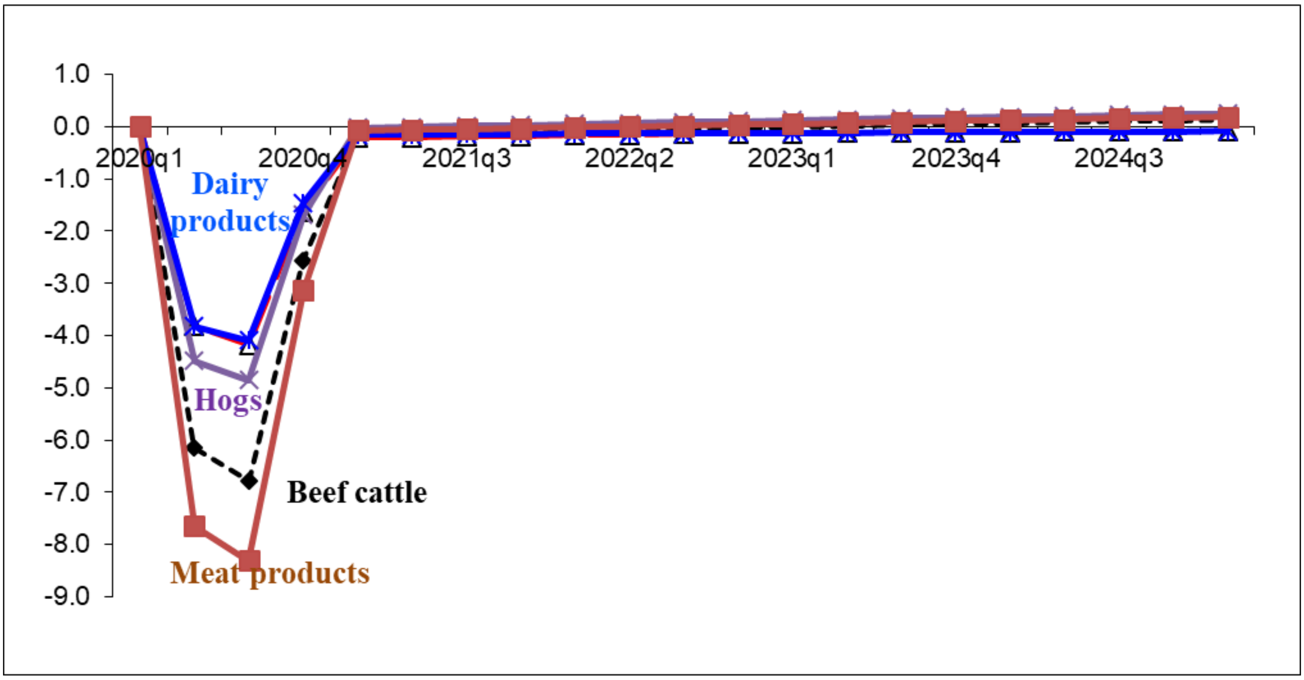


Figures 2.5 (East Central Iowa) and 2.6 (national) show output impacts in directly affected sectors. Reduced demand for livestock products impacts negatively on livestock production sectors. Sales decrease as processing plants for meat and dairy products across the nation reduce operating capacity in response to trade sanctions. With the lifting of trade sanctions in

the third and fourth quarters comes restoration of output. In East Central Iowa, beef cattle, dairy cattle and hogs output remains below base for a number of periods due to livestock destruction and depressed investment prior to lifting of trade sanctions.

An unexpected result in the scenario is that the Rest of USA suffers larger percentage output losses than either Iowan region. This arises from the location of ports through which meat and dairy products are exported. Ports in the Rest of Mid-West account for around 7.5% of such exports and Iowa 0%, while ports in the Rest of USA account for 92.5%. No demand shifts are imposed on domestic consumption in the scenario: the Iowan regions sell relatively large shares of livestock products to Iowa, and smaller shares to other regions than either Rest of Mid-West or Rest of USA. Hence, smaller shares of Iowan animal products are affected by trade sanctions than elsewhere in USA.

Figure 2.6: National industry outputs (% deviation from base)



The income-side shows that real GDP in East Central Iowa and Rest of Iowa falls below base in the first and second quarters of the outbreak due mainly to a fall in employment. This is reinforced by an exogenously imposed fall in livestock investment in these quarters. Effective capital falls below due to livestock destruction and, in meat and dairy products, reduced operating capacity during trade sanctions.

Figure 2.7: Income-side GDP in East Central Iowa (% deviation from base)

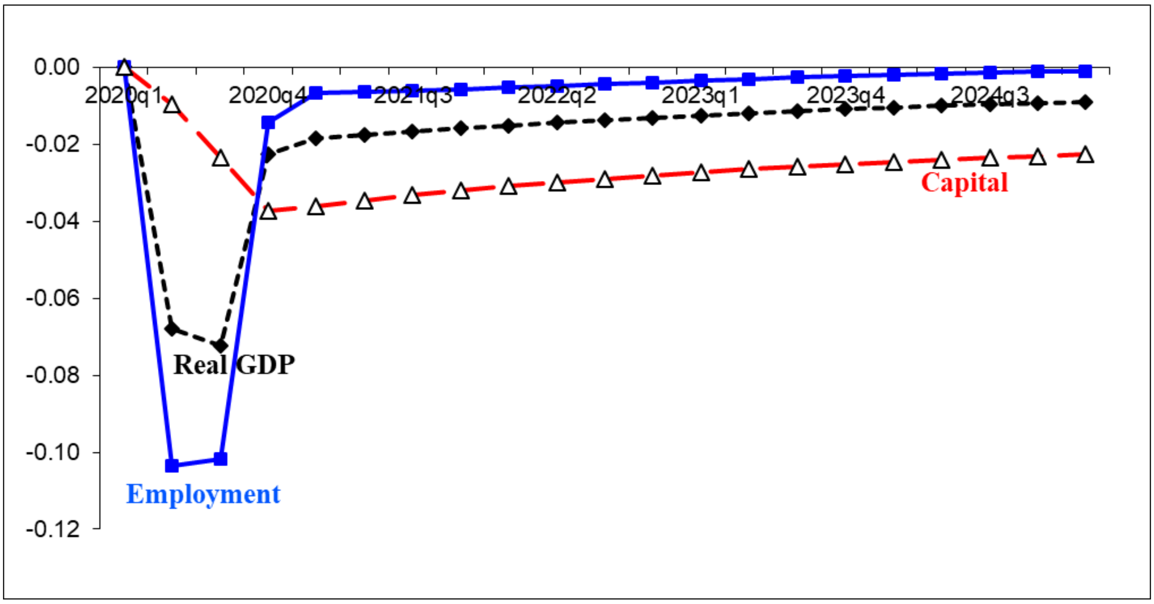


Figure 2.8: Income-side GDP in Rest of Iowa (% deviation from base)

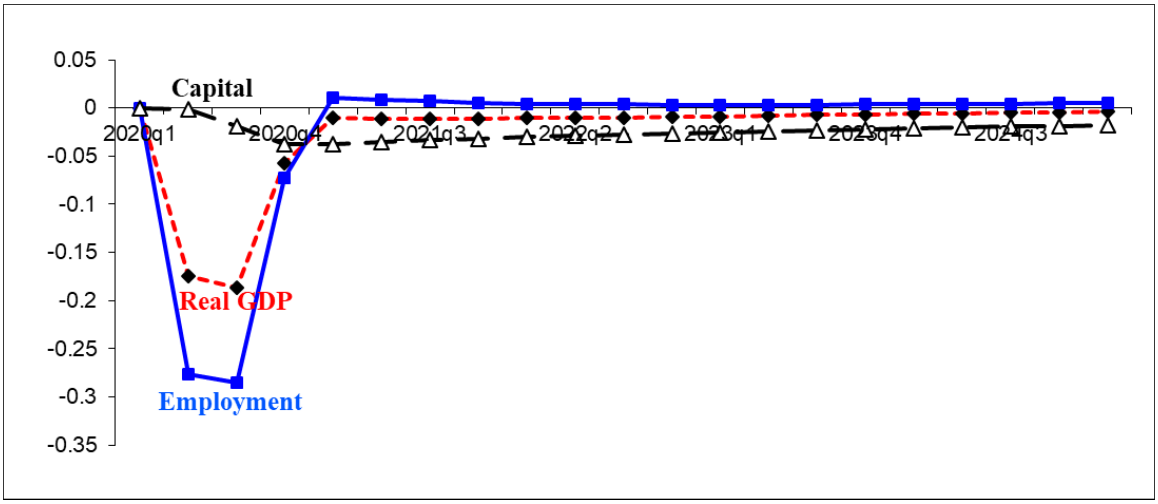


Figure 2.9: Income-side GDP in Rest of Mid-West (% deviation from base)

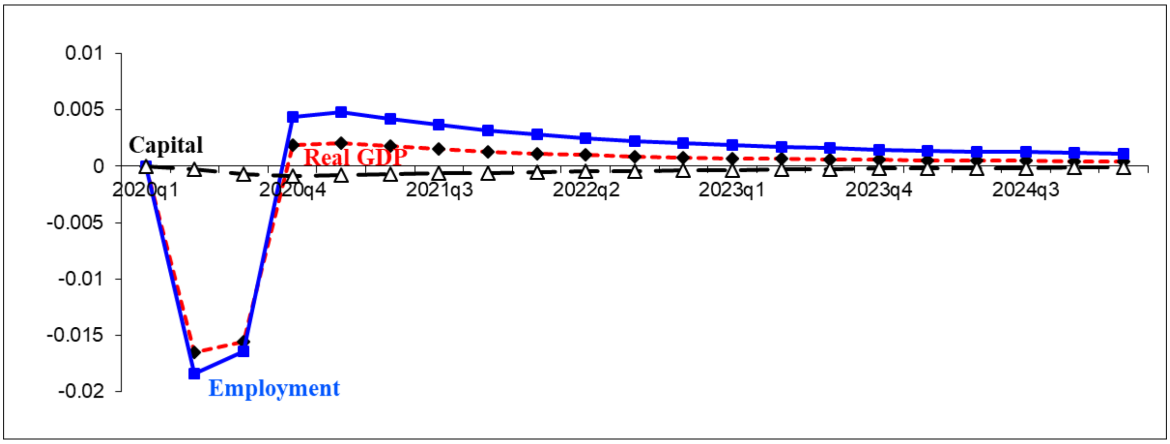
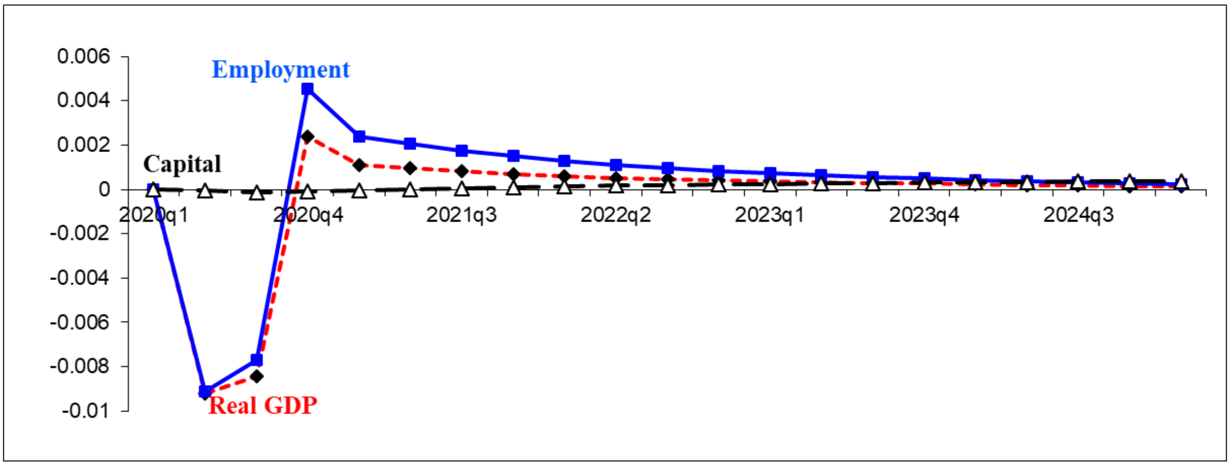
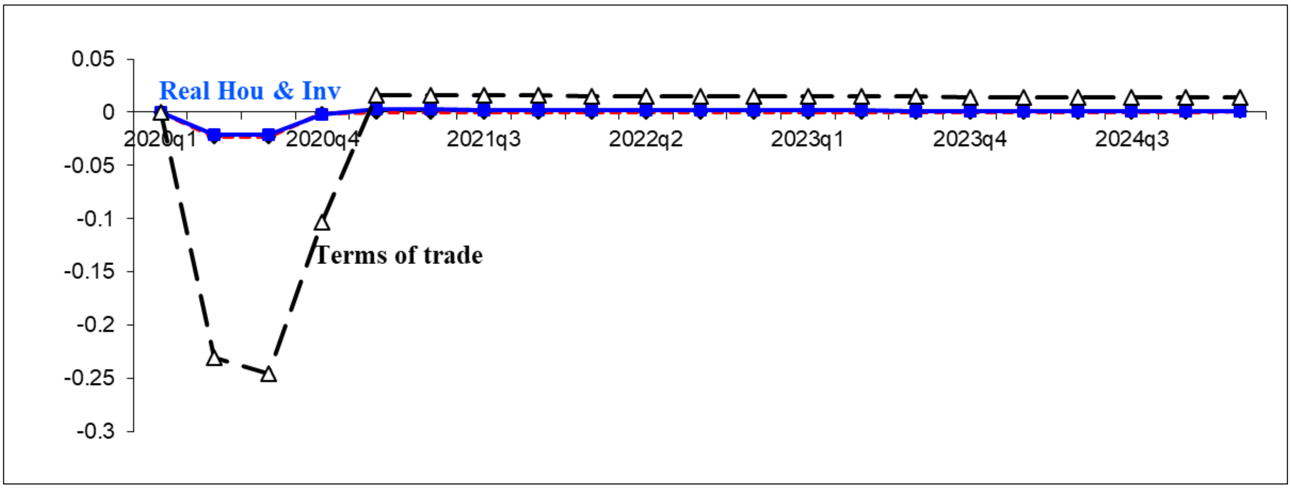


Figure 2.10: National income-side GDP (% deviation from base)



National real GDP falls by less than 0.01% relative to base in the first and second quarters (figure 2.10). But since the national terms of trade fall by around 0.25% relative to base due to the trade sanctions on livestock products, the proportional fall in aggregate consumption is larger in percentage terms (figure 2.11). In the two quarters with trade sanctions, national aggregate consumption falls to more 0.02% below base.

Figure 2.11: National aggregate consumption, investment and terms of trade (% deviation from base)



The deviation in welfare (dWELF) at the national level is calculated from the CGE modelling as:

$$\text{dWELF} = \sum_d \sum_t \frac{\text{dCON}_t^d + \text{dGOV}_t^d}{(1+r)^t} - \frac{\text{dNFL}_z}{(1+r)^z} + \frac{\text{dKstock}_z}{(1+r)^z} \qquad (2.1)$$

In (2.1), dCON and dGOV are the deviations in real aggregate household and government spending (i.e, current consumption) in region *d* (summed across all US regions) and period *t*; dNFL is the deviation in real net foreign liabilities in the final period (*z*) of the simulation; dKstock is the deviation in the real value of the capital stock in the final period (*z*) of the simulation; and *r* is the discount rate.

The impact of trade sanctions is shown through the terms-of-trade impact. Table 1.1 shows the contributions of terms of trade movements from base (row (1)).The sum of rows (2) and (3) across all periods to 2025q1 is minus $4.84 billion. This compares with a calculation from equation (1) of $4.96 billion. The terms of trade is the main driver of welfare impacts.

Table 2.1 Simplified contributions to welfare impact ($m)

Period	2020q2	2020q3	2020q4	2021q1
(1) Direct TofT (real)	-3121	-3293	-1322	334
(2) Consumption (real)	-1007	-1067	-118	-91
(3) Balance of trade (real)	-2793	-3013	-1810	421
(4) Welfare =(2)+(3)	-3800	-4080	-1927	330
(5) Discounted welfare	-3800	-4055	-1904	324

Delaying lifting of trade sanctions

In a variant on the scenario, half the trade sanctions remain in place for two further years instead of being fully lifted in 2020q4. This is contrary to international guidelines. There is a corresponding delay in full recovery in the labour market and the terms of trade.

Figure 2.12 shows that real wages persist below nationally, allowing employment to rise above base when half the sanctions are lifted in 2020q4.

Figure 2.12: National income-side GDP and real wages – slow sanction lifting variant (% deviation from base)

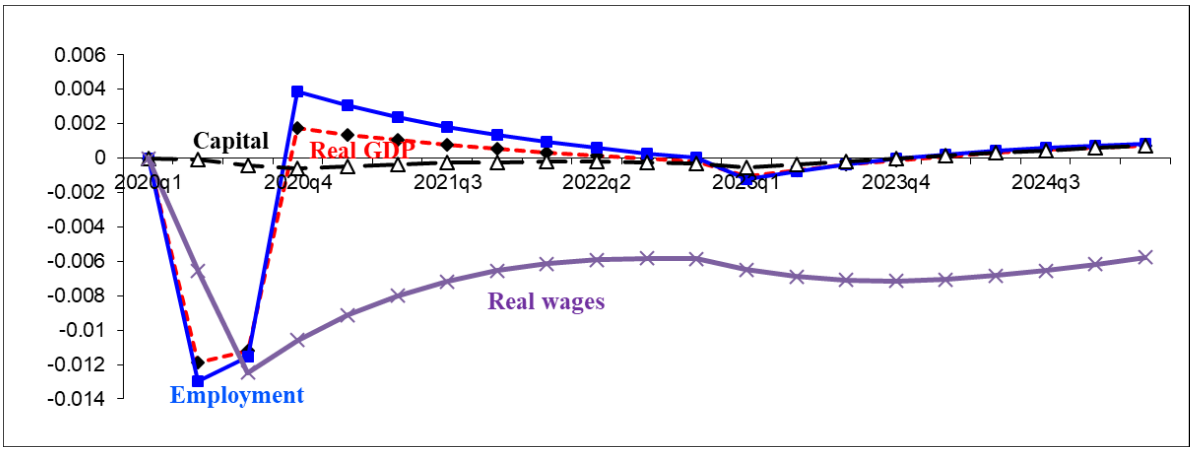
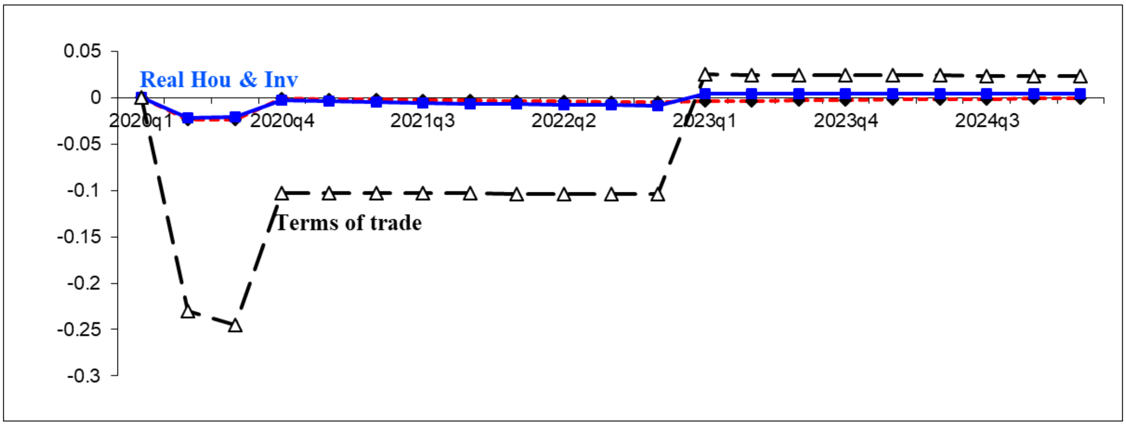


Figure 2.13: National aggregate consumption, investment and terms of trade – slow sanction lifting (% deviation from base)



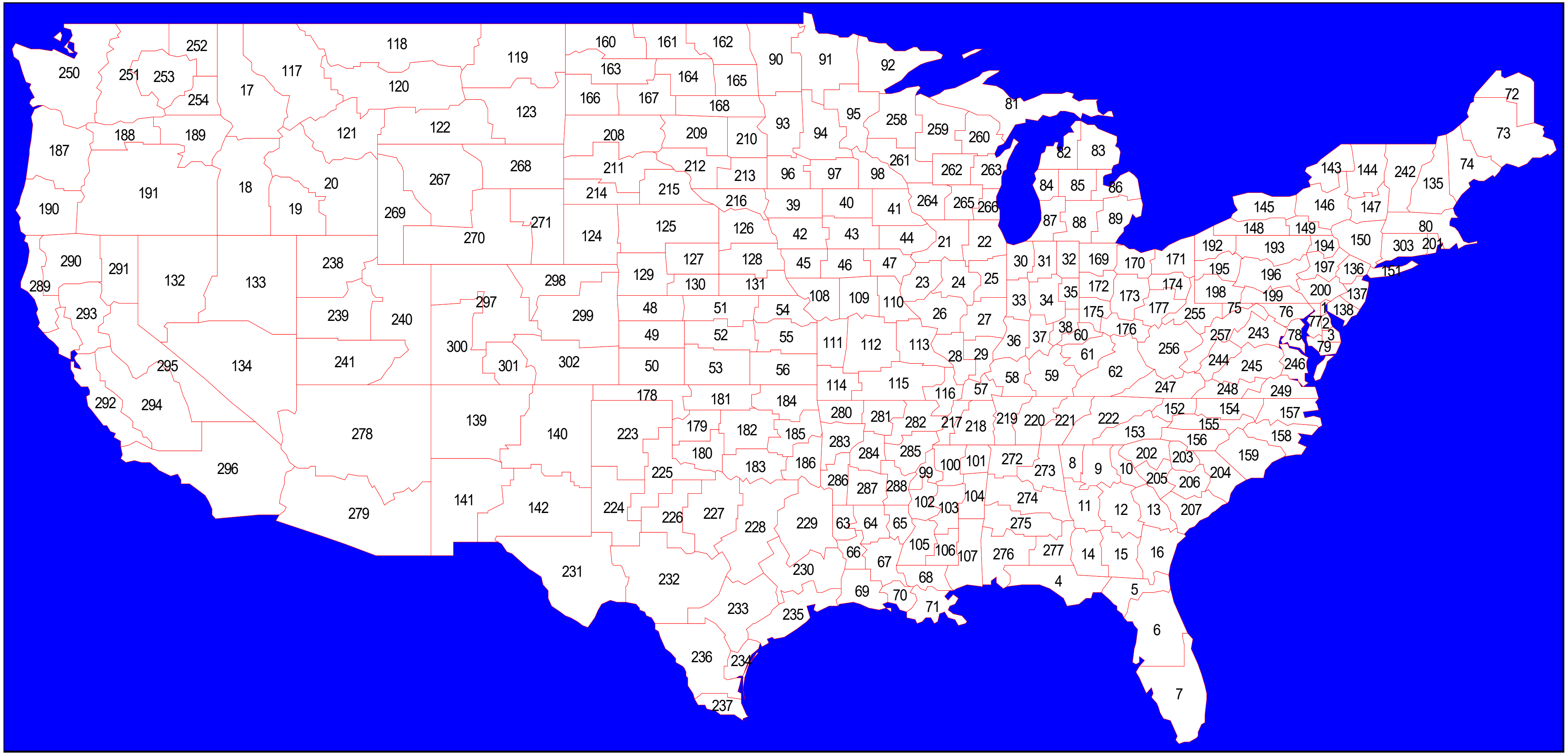
The welfare loss arising mainly from persistent below base terms of trade due to prolonged sanctions is $18.3 billion in net present value terms. Table 1.2 shows the first three quarters plus the last quarter (2022q4) with half of usual exports subjected to sanctions and the following quarter (2023q1) in which all sanctions are lifted. The discounted sum of real consumption and the balance of trade over all periods is minus $18.3 billion (based on a row (5) summed across all periods), aligning with the NPV calculation based on equation (2.1).

Table 2.2 Simplified contributions to welfare impact ($m) – slow sanction lifting variant

Period	2020q2	2020q3	2020q4	2022q4	2023q1
(1) Direct TofT (real)	-3121	-3293	-1322	-1201	663
(2) Consumption (real)	-1007	-1067	-118	-491	-450
(3) Balance of trade (real)	-2793	-3013	-1810	-1110	958
(4) Welfare =(2)+(3)	-3800	-4080	-1927	-1601	508
(5) Discounted welfare	-3800	-4055	-1904	-1505	474

Appendix A Regions of the agrifood version of USAGE-TERM

Figure A1: US agricultural districts (excluding Alaska and Hawaii)



Key to figure A1:

1	NthDE	39	NwIA	77	UpEShrMD	115	SCntMO	153	WstnMntNC	191	SeOR	229	ETxNthTX	267	NwWY
2	CntDE	40	NthCntLIA	78	SthMD	116	SeMO	154	NthPiedMntNC	192	NwernPA	230	ETxSthTX	268	NeWY
3	SthDE	41	NeIA	79	LoEShrMD	117	NwMT	155	CntPiedMntNC	193	NthCntPA	231	TrnsPECosTX	269	WestWY
4	NwFL	42	WCntIA	80	MA	118	NthCntLMT	156	SthPiedMntNC	194	NeernPA	232	EdwardsPltTX	270	SCntWY
5	NeFL	43	CntIA	81	UpperPenMI	119	NeMT	157	NthCstalNC	195	WCntPA	233	SCntTX	271	SeWY
6	CntFL	44	ECntIA	82	NwMI	120	CntMT	158	CntCstalNC	196	CntPA	234	CstalBndTX	272	NValAL
7	SthFL	45	SwIA	83	NeMI	121	SwMT	159	SthCstalNC	197	ECntPA	235	UCstTX	273	MtEValAL
8	NwGA	46	SCntIA	84	WCntMI	122	SCntMT	160	NwND	198	SwernPA	236	SthTexasTX	274	UpPlnPdmtAL
9	NthCntLGA	47	SeIA	85	CntMI	123	SeMT	161	NthCntLND	199	SCntPA	237	LowerValTX	275	BlackbeltAL
10	NeGA	48	NwKS	86	ECntMI	124	NwNE	162	NeND	200	SeernPA	238	NthUT	276	CstPlGlfAL
11	WCntGA	49	WCntKS	87	SwMI	125	NthNE	163	WCntND	201	RI	239	CntUT	277	WiregrassAL
12	CntGA	50	SwKS	88	SCntMI	126	NeNE	164	CntND	202	NwSC	240	EstnUT	278	NthAZ
13	ECntGA	51	NthCntLKS	89	SeMI	127	CntNE	165	ECntND	203	NthCntLSC	241	SthUT	279	SthAZ
14	SwGA	52	CntKS	90	NwMN	128	EstNE	166	SwND	204	EstnSC	242	VT	280	NwAR
15	SCntGA	53	SCntKS	91	NthCntLMN	129	SwNE	167	SCntND	205	WCntSC	243	NthVA	281	NthCntLAR
16	SeGA	54	NeKS	92	NeMN	130	SthNE	168	SeND	206	CntSC	244	WstnVA	282	NeAR
17	NthID	55	ECntKS	93	WCntMN	131	SeNE	169	NwOH	207	SthSC	245	CntVA	283	WCntAR
18	SwID	56	SeKS	94	CntMN	132	NwNV	170	NthCntLOH	208	NwSD	246	EstnVA	284	CntAR
19	SCntID	57	PuchaseKY	95	ECntMN	133	NeNV	171	NeOH	209	NthCntLSD	247	SwernVA	285	ECntAR
20	EastID	58	MidWstnKY	96	SwMN	134	SthNV	172	WCntOH	210	NeSD	248	SthVA	286	SwAR
21	NwIL	59	CntKY	97	SCntMN	135	NH	173	CntOH	211	WCntSD	249	SeernVA	287	SCntAR
22	NeIL	60	NthKY	98	SeMN	136	NthNJ	174	ECntOH	212	CntSD	250	WstnWA	288	SeAR
23	WestIL	61	BluegrassKY	99	UpperDeltaMS	137	CntNJ	175	SwOH	213	ECntSD	251	CntWA	289	NthCstCA
24	CntIL	62	EoMtKY	100	NthCntLMS	138	SthNJ	176	SCntOH	214	SwSD	252	NeWA	290	SiskiyouShCA
25	EastIL	63	NwLA	101	NeMS	139	NwNM	177	SeOH	215	SCntSD	253	ECntWA	291	NeCA
26	WestSwIL	64	NthCntLLA	102	LowerDeltaMS	140	NeNM	178	PanhandleOK	216	SeSD	254	SeWA	292	CntCstCA
27	EastSeIL	65	NeLA	103	CntMS	141	SwNM	179	WCntOK	217	DeltaTN	255	NwWV	293	SacramntVaCA
28	SwIL	66	WCntLA	104	ECntMS	142	SeNM	180	SwOK	218	WestTN	256	SwWV	294	SanJoaquinCA
29	SeIL	67	CntLA	105	SwMS	143	NthNY	181	NthCntOK	219	WstnRIMTN	257	EstnWV	295	SierraMtCA
30	NwIN	68	ECntLA	106	SCntMS	144	NeNY	182	CntOK	220	CntBsnTN	258	NwWI	296	SouthCA
31	NthCntLIN	69	SwLA	107	SeCstMS	145	WstnNY	183	SCntOK	221	CmblndPlTN	259	NthCntLWI	297	NWMtnCO
32	NeIN	70	SCntLA	108	NwMO	146	CntNY	184	NeOK	222	EstTN	260	NeWI	298	NeCO
33	WCntIN	71	SeLA	109	NthCntLMO	147	EstnNY	185	ECntOK	223	NHiPlainSTX	261	WCntWI	299	ECntCO
34	CntIN	72	NthME	110	NeMO	148	SwNY	186	SeOK	224	SHiPlainTX	262	CntWI	300	SwCO
35	ECntIN	73	CntME	111	WestMO	149	SthNY	187	NwOR	225	NLowPlnTX	263	ECntWI	301	SanLuisCo
36	SwIN	74	SthME	112	CntMO	150	SeNY	188	NthCntOR	226	SLoPlnTX	264	SwWI	302	SeCO
37	SCntIN	75	WstnMD	113	EastMO	151	LongIslandNY	189	NeOR	227	CrossTimbTX	265	SCntWI	303	CT
38	SeIN	76	NthCntLMD	114	SwMO	152	NthMntnNC	190	SwOR	228	BlacklandsTX	266	SeWI		

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