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Appendix: Documentation of the ABARES/NCAP agristaples CGE model for India

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1 Introduction

The purpose of this appendix is to document the ABARES/NCAP agristaples CGE model for India. This model was developed by the Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES) and the National Centre for Agricultural Economics and Policy Research (NCAP) for the DFAT project 'Managing agricultural price risk: implications for India'. The objective of the project is to develop a model that can analyse the impacts of agricultural price changes and related policy options on the Indian economy and Indian households.

Indian agristaples policies

Agristaples are staple food products, typically grains or cereals, essential for the nutritional wellbeing of a population. In India, the principal agristaples considered in this project are wheat and rice.

The dependence of India's population on agristaples has led to development of government policies which support the domestic market. The key Indian policies relating to agristaples aim to reduce adverse impacts on producers and consumers from changes in their price. For producers, one such policy is the minimum support price which assists producers by guaranteeing a set price when the market price falls. Consumers, particularly low income consumers, are protected from a rise in the market price of agristaples by a policy which fixes the price at a level lower than the market price for a certain quantity of agristaple for each household (known as rationed purchases).

One of the key instruments the Government of India uses to manage these policies is its stockpiling operation. Government purchases from producers increase the stockpile and the sale of agristaples at a subsidised price are drawn from the stockpile. Because production of agristaples in India has been increasing over the past decade, the size of the national stockpile has been growing. The existing capacity limit has led the Government of India to utilize trade as an instrument to manage the stockpile in those instances. By exporting wheat and rice, the stockpiles were drawn down in those years.

ABARES/NCAP agristaples model

The ABARES/NCAP agristaples model is a single country, computable general equilibrium model (CGE) designed to simulate the key producer and consumer agristaples policies in India, such as the ones discussed above. It also allows for alternative instruments to meet overall policy goals.

The model is dynamic. Commodity producers, consumers and governments make decisions over time with myopic foresight, mindful of current economic conditions. Private investors in physical capital or in agristaple stocks make decisions in response to future profit opportunities assuming perfect foresight. Capital stocks increase with investment in physical capital. The population and labour force change at assumed rates over the simulation period. Given the use of intertemporal investment dynamics, each simulation conceptually involves solving the model for each of the model's time periods simultaneously. In particular, in the simulation report, the model is run with annual time periods over twenty years starting from a base year using 2004–05 data. It is solved as a two-point boundary problem in optimal control with discrete time, taking into account terminal value issues.

Traditionally, models of Indian policies have been conducted within a partial equilibrium framework. They included both static models (see Landes, Jha & Srinnivasan 2007) and dynamic models. The CGE framework employed in the design of the ABARES/NCAP agristaples model shares core features with the standard model used by the International Food Policy Research Institute (IFPRI) (Lofgren et al. 2002). Unlike the IFPRI model, the ABARES/NCAP agristaples model is dynamic and allows for forward looking behaviour, namely in regard to investment in physical capital and for private agristaples storage. The model's simulation horizon of twenty 20 years is commensurate with an assumed succession of Five Year Plans. Another benefit of a dynamic model is that it allows the demand curves for wheat and rice to shift with changes in real incomes and for supply curves to shift with changes in the real costs of production. In principle, both curves can shift following any change in relative prices of substitutes or complements in consumption or production.

As in Landes et al. (2007), the ABARES/NCAP agristaples model is written in GAMS in mixed complimentarity format. This means that, despite being a CGE model, the model also incorporates mathematical programming features more common to partial equilibrium framework. One such feature is the ability to turn variables on and off when changes in economic conditions occur in the model simulation. This flexibility is important for analysis of policies and private activities. Another typical partial equilibrium feature in the model is the assumption that products are perfect substitutes.

Using the model

The model is implemented in the General Algebraic Modeling System (GAMS) using the PATH solver for mixed complimentarity problems.

This appendix to the ABARES/NCAP agristaples model fully documents the model equations in GAMS code. To navigate the model, it is advised that course notes and exercises from the ABARES modelling workshop (May 2013) be consulted. That course was developed with complete knowledge of the model code to ensure comprehensive understanding of the model's content and capacity. The training documents provide exercises which guide the user, including those with limited modelling experience, through the construction of the model's equations. The user is guided, from first principles, through a partial equilibrium modelling exercise to eventually understanding how to build a dynamic, forward looking CGE model in GAMS.

One of the strengths of the existing ABARES/NCAP agristaples model is that it can be extended and modified to more accurately reflect real world policy features. It was the benefit of constructing a model with such flexibility that led ABARES and NCAP to invest in the development of the current model rather than to use an available version of the Global Trade Analysis Project (GTAP).

Sectoral, factor and household coverage

Sector coverage

The model's database is kept highly aggregated with a minimal level of detail provided to study wheat and rice agristaples.

Table 1 lists the currently available sectoral and sub-sectoral detail. Currently, separate commodities are distinguished at the sub sectoral level. By construction the model's structure may be equally applied to a model with a fine level of sectoral detail. This is principally a matter of database development.

Table 1 Sectoral and sub sectoral industry coverage

Agristaples
Rice
Wheat
Other agriculture
Other grains
Other crops
Other agriculture (also called livestock products)
Other primary industry (also called mining, forestry and fishing)
Manufacturing
Food processing
Other manufacturing
Services
Transport services
Non-transport services

Primary factor coverage, supply and use

The model has various types of primary factors of production: a sub-sector specific primary factor, mobile unskilled and skilled labour, mobile general and sub-sector specific capital. Note that skilled labour is used in other primary industry (for example in mining), in manufacturing and in services but is not used in agriculture. Sub-sector specific capital is used in each of the footloose manufacturing and service sub-sectors. The use of a fixed specific factor in each of the primary industries amounts to adding upward slope to the supply curve of industry output, constraining production responses to real profit shocks. By contrast, in the footloose industries there are no exogenous specific factor supplies. In these cases, supply response is therefore particularly responsive to economic conditions, constrained only by the overall availability of mobile factors in the long run but in the short run also by existing specific capital available after allowance for relative price induced factor substitution.

As already noted, capital supplies are determined endogenously in the model while the time paths of all other factor supplies are exogenously given. Demands for all factors of production are responsive to relative costs. In the model all types of capital are kept intact through regular maintenance rather than being allowed to depreciate. A higher exogenous real interest rate is used to account for this lack of capital depreciation.

Household group coverage

The model may be used to illustrate the impacts of economic shocks on different household groups, allowing for full income feedback from spillovers to the rest of the economy. Available household group coverage in the model's database is from the national sample survey of consumption expenditure and employment status. On this basis, the groups distinguished in the model are:

- rural non-agricultural self employed
- rural agricultural labour
- rural other labour
- rural agricultural self employed

- rural other households
- urban self employed
- urban salaried class
- urban casual labour
- urban other households.

Applications

This model was purpose built to analyse the effects of agriculture policies and agriculture-related external shocks, such as commodity price variation. The model's main use is for comparative dynamic policy analysis. That is, it is used to illustrate the sensitivity of impacts on different household groups, allowing for full-income feedback from spillovers to the rest of the economy. Specifically, the model can examine the economy-wide impacts of:

- short and long-term changes to domestic and world commodity prices
- changes to trade policies
- changes to government or private stockpiling behaviour

Existing CGE models

The modelling approach used for the ABARES/NCAP agristaples model draws from literature by experts, such as Thomas Rutherford and Michael Keyzer. Additionally, Kirit Parikh and colleagues also developed a CGE model for India (www.irade.org/KiritParikh-detailedCV.htm). The Partnership for Economic Policy (PEP) network and its CGE development work, including a comparative static Indian CGE model, is also available for analysis on Indian policies. CGE work is also being undertaken at the Organization of Economic Co-operation and Development (OECD). This work uses the Development Policy Evaluation Model (DEVPEM) for analysis on the impact of high transaction costs which limit the separation of production and consumption decisions for some households.

Lastly, research by Lofgren and colleagues at the World Bank use the Maquette for Millennium Development Goals Simulations (MAMS) framework. MAMS uses a dynamic myopic modelling framework from which there is scope to learn about parallel modelling efforts. Currently there are no MAMS applications for India.

Structure of the appendix

This appendix is designed for readers that have some familiarity with the GAMS coding language for a mixed complimentarity format.

The first section of this appendix provides a general introduction to the ABARES/NCAP agristaples model. The remaining sections provide the algebraic description of the model. The model notation is first presented with sets, parameters and variables given in sections 2 through 4. Sections 5 through 14 cover the equation modules in the GAMS code. In these sections, supporting explanation of key concepts and policy significance is provided.

Section 15 covers possible scenario design, specifying the collection of simulations that can be readily undertaken using the ABARES/NCAP agristaples model. Section 16 outlines the economic growth calibration approach used for policy analysis and the model extensions that were used in the illustrative simulations presented in the body of this report. Specifically, the extensions cover the calibration to an unbalanced growth path and inclusion of an existing government consumer subsidy for agristaples.

2 Model notation– Sets used in the model

t time periods /01,..,20/

tf(t) first time period /01/

tl(t) last time period /20/

In defining the above time index for simulation periods, it may be noted that the current setting is for a simulation run from year 1 to year 20. Note that the base-year data is for 2004-05.

c commodities and industries with elements

/crice,cwhet,cogrn,cocrp,clive,cminx,

cfdpc,cmanf,ctmrg,cserv/

Industries in the model produce a single good that is industry specific in the model's database. The short names for commodities refer to rice; wheat; other grains; other crops; other agriculture (specifically livestock products) other primary industry (specifically mining, forestry and fishing industries); food processing; other manufacturing; transport services; and non-transport services. Rice and wheat are the agristaple commodities (staple agricultural commodities) in the model. Some useful subsets of commodities are as follows.

cstk(c) agristaple commodities /crice,cwhet/

cnstk(c) all elements in c that are not in cstk(c)

cexch(c) commodity price determined by numeraire equation /crice/

cnexch(c) all elements in c that are not in cexch(c)

fg all primary factors of production

This is the union of subsets fgncap and fgcap.

fgncap(fg) primary factors of production excluding physical capital with elements

/frice,fwhet,fogrn,focrp,flive,fflbbs,fflbsk,ffnatr/

The first five elements of fgncap are industry specific agricultural land types. Having these specific factors reduces the tendency for specialization in agriculture. The next two elements refer to basic (unskilled) labour and skilled labour. In the base-year database, unskilled labour is used in every industry of the economy while skilled labour is used in every non-agricultural industry. The last element is a natural resource that is specific to mining, forestry and fisheries.

fgcap(fg) primary physical capital factors of production

This is the union of subsets fggn and fgsp.

fggn(fg) general physical capital /ffcapt/

fgsp(fg) industry specific physical capital /ffdpc,fmanf,ftmrg,fserv/

General capital, fggn, is mobile capital that is used throughout the economy. Sector specific capital, the relevant element in fgsp, is capital that, once installed in the industry, is fixed there. Only non-agricultural industries have sector-specific capital in the model's database.

hh household groups with elements/

rnase	Rural non-agricultural self employed
ral	Rural agricultural labour
rol	Rural other labour
rase	Rural agricultural self employed
roh	Rural other households
use	Urban self employed
usc	Urban salaried class
ucl	Urban casual labour
uoh	Urban other households/

hhli(hh) consumer subsidy target groups /ral,ucl/

As previously noted, the household groups are those defined in the model's database. They reflect the employment and income status in selected national sample survey information (Ojha et al. 2009).

3 Model notation– Parameters used in the CGE model

Dummy variables

dvpwn	dummy is 1 if world price is endogenous for an agristaple
dvfacg(fg,c)	dummy is 1 if the primary factor is used by the industry
dvaut	dummy is 1 under general policy of autarky for an agristaple

Miscellaneous unit cost items

utc(c)	unit transport cost to world market in world currency
ucbs(cstk)	local unit storage cost of an agristaple
ucts(cstk)	unit transport cost for an agristaple to and from the local silos

Opening asset volumes and limits

Stockpile of an agristaple

stk0(cstk)	initial opening level of an agristaple stock
stklo(cstk)	lower working limit on an agristaple stock
stkup(cstk)	upper capacity limit on an agristaple stock

Physical capital

capgn0	initial opening level of general physical capital
capsp0(fgsp)	initial opening level of industry specific physical capital

Taxes

txmt(t,c)	standard ad valorem import tariff (fraction)
txet(t,c)	standard ad valorem export tax (fraction)
txpd(c)	ad valorem consumption tax (fraction)
txps(c)	ad valorem production tax (fraction)
htax(t,hh)	ad valorem household tax (fraction)

The household tax, htax, is zero in the model database.

Price bands

pshi(cstk)	upper limit on producer price of an agristaple
pslo(cstk)	lower limit on producer price of an agristaple

Consumer agristaples subsidies

qdchbar(t,c,hh)	baseline simulation real consumption of commodity
cfac(c)	conversion factor to rice equivalent in calorific terms

In the simulations, only each of the agristaples has a non-zero value for qdchbar and cfac.

Behavioural elasticities and related terms

Rest of world (row)

eyrow(cstk)	real income elasticity of demand for an agristaple by row
edrow(cstk)	real own price elasticity of demand for an agristaple by row
esrow(cstk)	real own price elasticity of supply for an agristaple by row

Local production

sigmapva(c)	CES elasticity of substitution between factors of production
alphag(fg,c)	base year factor cost share in value added

Capital creation

ioinv(c)	base year input output coefficient for capital creation

Household groups

shryg(hh,fg)	household share in factor income
mps(hh)	marginal and average propensity to save
cmin(t,c,hh)	minimum level of real consumption
cles(c,hh)	household super numeracy expenditure share on good

Investment adjustment costs

gammagn	adjustment cost term for investment in general physical capital
gammasp(fgsp)	adjustment cost term for investment in industry specific physical capital

Technical change (shock terms) and related terms

Rest of world

prdshkrowi(t,cstk)	rest of world production technology shock index
prdstdrowi(t,cstk)	rest of world standard production technology shifter index

Local production

tcioi(t,c2,c)	technical change index for input-output coefficient
io0(c2,c)	base year input-output coefficient
faugtcgi(t,fg,c)	primary factor augmenting technical change index

General economic conditions

Local conditions

r	the domestic real interest rate
dr(t)	the domestic real discount rate
gfac	the baseline rate of balanced domestic economic growth (real gdp growth as fraction)
fsg(t,fg)	total factor supply (exogenous for subset fngcap)
gadji(t)	real government expenditure index
cpi	the local consumer price index
cwts(c)	base year value shares in total consumption (fraction)
tiny	a small number such as 1.0e-06 for solving the hybrid government stockpile problem

Rest of world

pwexo(t,c)	the world real price of the commodity in world currency
yrowi(t,cstk)	rest of world real gdp index base year value 1, shifts row demand for agristaple out
fsav(t)	rest of world savings used by local economy in world currency

The world price is endogenous when the large country assumption is used for cstk, each of the agristaples.

4 Model notation – List of variables

Module of price linkages and trade determination

pm(t,c)	domestic import price
pe(t,c)	domestic export price
ps(t,c)	domestic good producer price
qe(t,c)	quantity of exports
qm(t,c)	quantity of imports

Module of world price determination for an agristaple

pwn(t,c)	world price of commodity
pwstap(t,c)	world price of an agristaple
qdrow(t,cstk)	rest of world consumption of an agristaple
qsrow(t,cstk)	rest of world production of an agristaple

Module of specific agristaples policies

Private stockpile ('pstk')

qslp(t,cstk)	quantity sold from private stockpile
qbyp(t,cstk)	quantity bought for private stockpile
stkprv(t,cstk)	private stockpile level end of period
pstk(t,cstk)	price of a unit of commodity in the private stockpile
pstklop(t,cstk)	shadow subsidy from lower working limit on private stockholding
pstkupp(t,cstk)	shadow tax from upper capacity limit on private stockholding

Variable trade measures price band ('vtpb')

extxmsv(t,c) price	variable export tax or import subsidy (ad valorem fraction) to support ceiling under vtpb
exsbmtv(t,c) price	variable export subsidy or import tariff(ad valorem fraction) to support floor under vtpb

Government buffer stockpile ('gstk')

qslg(t,cstk)	quantity sold from government stockpile
qbyg(t,cstk)	quantity bought for government stockpile

extxmsg(t,c) price	variable export tax or import subsidy (ad valorem fraction) to support ceiling under government buffer stockpile with international trade
exsbmtg(t,c) price	variable export subsidy or import tariff (ad valorem fraction) to support floor under government buffer stockpile with international trade
pqslgup(t,cstk)	shadow tax from upper limit on sales from government stockpile
pqbygup(t,cstk)	shadow tax from upper limit on purchases for government stockpile
stkgov(t,cstk)	government stockpile level end of period for an agristaple

Module of variable consumer subsidy with ration coupon for an agristaple

pcsubln(t,hh)	shadow price of targeted and non-traded low income specific minimum agristaple consumer quota
pcsuban(t,hh)	shadow price of untargeted and non-traded minimum agristaple consumer quota
pcsubat(t)	shadow price of untargeted and traded minimum agristaple consumer quota

Module of commodity production by industry

qs(t,c)	total output of commodity and level of industry activity
pva(t,c)	price of value added
fdg(t,fg,c)	factor use by industry activity
qdint(t,c)	total intermediate use of commodity

Module of domestic end user incomes

yfhg(t,hh,fg)	nominal factor income to household group
yh(t,hh)	total household group nominal income
grev(t)	total nominal government revenue

Module of domestic end user expenditures

qdch(t,c,hh)	real private household group consumption of commodity
qdc(t,c)	total real private consumption of commodity
is(t)	production of capital good created

qdinv(t,c)	real investment expenditure on commodity to create capital good
qdgov(t,c)	real government consumption of commodity
gexp(t)	total nominal government expenditure

Module of market balances

pd(t,c)	local consumer price
wfg(t,fg)	local factor price
exr(t)	exchange rate in US dollars per world currency
iadj(t)	endogenous technical advance in capital good creation (as fraction)
pi(t)	creation price of capital good

Module for capital good accumulation and use

idgn(t)	level of investment in general physical capital
idsp(t,fgsp)	level of investment in sector specific physical capital
capgn(t)	level of available general physical capital
capsp(t,fg)	level of available sector specific physical capital
pcapgn(t)	asset price of general physical capital (substituted out in implementation)
pcapsp(t,fgsp)	asset price of industry specific physical capital (substituted out in implementation)

Walras' Law check variable

walras(t)	check of Walras law should be zero

All variables are defined to be positive with the exception of the variable walras which is an extraneous variable.

5 Model equations – A note

The model algebra presented in the sections that follow adopts GAMS-like notation for easy reference to the modelling code.

The name of each equation identifies the variable it determines. This is required for equations with inequalities because it enables GAMS to infer complementary slackness conditions. Variables whose set ranges are not meaningful are fixed to zero prior to solving. Where equations include exogenous base-year values, a zero is appended to the name.

All base-year values are in US$2004–05 billion, reflecting sourcing of the core data from the GTAP database. All prices are relative to the purchase of 1 unit of the numeraire good, which is a constant domestic consumption basket. The price of foreign exchange is US dollars per world currency per unit of the domestic consumption basket.

Some model equations are only used in particular simulation environments (see section 14 below). The last section mainly concerns model extensions to cover an unbalanced growth path, as used in the simulation report.

6 Model equations – Module of price linkages and trade determination

Import parity price definition

pm_dfeq(t,c)..pm(t,c)=exr(t)*(pwn(t,c)+utc(c))*(1+txmt(t,c)+

(exsbmtv(t,c)-extxmsv(t,c)+exsbmtg(t,c)-extxmsg(t,c))$cstk(c))

In the absence of distortions, the import parity price in local dollars is the exchange rate adjusted world price plus a unit transport cost from the world market. Landed prices may then be adjusted by various possible trade measures. In the model database there is an existing ad valorem import tariff for some commodities. For the agristaples, indicated by the $cstk(c) conditional if, variable export subsidies/import tariffs and variable export tax/import subsidies may be used to enforce price band floors and ceilings on producer prices.

Export parity price definition

pe_dfeq(t,c)..pe(t,c)=exr(t)*(pwn(t,c)-utc(c))*(1-txet(t,c)+

(exsbmtv(t,c)-extxmsv(t,c)+exsbmtg(t,c)-extxmsg(t,c))$cstk(c)

In the absence of distortions, the export parity price in local dollars is the exchange rate adjusted world price less a unit transport cost to the world market. The trade measures include any existing base year export tax for some commodities and variable measures to support a price band.

Export supply arbitrage condition

qe_arbeq(t,c)..ps(t,c)≥pe(t,c)

If the cost to export exceeds the export parity price, then exports will not occur. Otherwise, exporting takes place until the domestic price rises to the export parity price.

Import demand arbitrage condition

qm_arbeq(t,c)..pm(t,c)≥ps(t,c)

The import demand arbitrage condition is symmetric to the export supply arbitrage condition. If the cost to import exceeds the local price, then imports will not occur. Otherwise, importing takes place until the domestic price falls to the import parity price.

From the above conditions, the local price is at most the import price and at least the export parity price. It is not profitable to trade if the local price is within these bounds. In the absence of trade distortions, the producer price can at most differs from the world price by twice the unit transport cost.

Producer price link to consumer price

ps_dfeq(t,c)..ps(t,c)*(1+txpd(c))=pd(t,c)

The local consumer price is the producer price marked up by any consumption tax on commodity use in the baseline database.

7 Model equations – Module of world price determination for an agristaple

World price definition

pwneq(t,c)..pwn(t,c)=pwexo(t,c)$cnstk(c)+pwstap(t,c)$cstk(c)

In the model the default setting is that the world price of each commodity is set exogenously. It is possible to endogenise the price. How this is done is shown below for each of the agristaples.

World market balance for an agristaple

pwstapeq(t,cstk)$dvpwn..

qs(t,cstk)+qsrow(t,cstk)+qslg(t,cstk)+qslp(t,cstk)=

(qdint(t,cstk)+qdc(t,cstk)+ qdgov(t,cstk)+qdinv(t,cstk))+

qdrow(t,cstk)+qbyg(t,cstk)+qbyp(t,cstk)

The large country assumption is adopted for each of the agristaples if dvpwn is set to 1 rather than zero. If dvpwn is 1, then pwstap is determined here to balance global demand and supply, otherwise it is set exogenously from pwexo and this equation does not apply.

The left hand side comprises supply from domestic and rest of world sources plus sales from domestic government and private stockpiles as applicable in the simulation settings. The right hand side comprises domestic demand by firms for intermediate use, household, government and investment end uses and aggregate demand by the rest of the world and purchases for the domestic government and private stockpiles of agristaples. A world commodity price is endogenised by additionally specifying a world price sensitive aggregate rest of world demand and rest of world supply function.

Rest of world aggregate demand function for an agristaple

qdroweq(t,cstk)..

(qdrow(t,cstk)/qdrow0(cstk))=(yrowi(t,cstk)**eyrow(cstk))*

((pwstap(t,cstk)/pwstap0(cstk))**edrow(cstk))

The rest of world demand curve is an elasticity weighted log linear function of exogenous rest of world real income shifter and of the world price of an agristaple.

Rest of world aggregate supply functions for an agristaple

qsroweq(t,cstk)..

(qsrow(t,cstk)/qsrow0(cstk))=(prdshkrowi(t,cstk)*prdstdrowi(t,cstk))*

((pwstap(t,cstk)/pwstap0(cstk))**esrow(cstk))

The rest of world supply curve is an elasticity weighted, log-linear function of the exogenous rest-of-world real output shifter and of the world price of the agristaple. The output shifter comprises standard or normal conditions over time, and an additional shifter for exogenous shocks. If there is a technical advance (cost reduction) in rest-of-world production of X per cent for an agristaple, then prdshkrowi increases by fraction X. If the small country assumption is imposed, then this is instead reflected in a world price fall of X per cent in the case of a technical advance of X per cent.

8 Module of specific agristaple policies

In the model there are four options to address intertemporal variation in domestic agristaple prices. They include

1) undertaking no specific policies
2) permitting domestic private stockholding behaviour in an attempt to allow the market to conduct privately optimal price smoothing
3) using variable trade measures to enforce a domestic price band when spatial international trade is allowed, and
4) enforcing a price band using a hybrid form of a domestic government buffer stock scheme.

Of the first two options, it would be expected that the second option would dominate from an efficiency perspective because it offers a less constrained trading solution, for example when the world price is influenced by private stockholding purchases and sales on the local market. The last option relies on variable trade measures to enforce the price band once buying or selling outside stock limits has been reached when trade is possible. However, this buffer scheme does not enforce the price limits when stock limits are hit under autarky. This last option was used in the ABARES main report.

Private stockpiling behaviour

It may be noted that the private stockpiling optimisation problem from which the dual price arbitrage conditions (found further below) are derived is to maximise the objective function:

sum(t,dr(t)*(ps(t,cstk)*(qslp(t,cstk)-qbyp(t,cstk)) –

ucbs(cstk)*stkprv(t,cstk)-ucts(cstk)*(qslp(t,cstk)+qbyp(t,cstk))))

subject to the private stock constraints that follow.

The objective function is the net present value of sales less purchases for the stockpile evaluated at the domestic market price less the cost of operating and maintaining the stockpile less the cost of transporting product from the market to and from the stockpile. The cost of investing in the stockpile is also accounted for through the equation which requires total nominal savings to equal total nominal investment to uphold Walras's law.

Private stock accumulation constraint

pstk_accumeq(t,cstk).. stkprv(t-1,cstk)+stk0(cstk)$tf(t)+

qbyp(t,cstk)-qslp(t,cstk)≥stkprv(t,cstk)

The private stock accumulation constraint necessitates that end of period’s private stockpile cannot exceed what was carried over from the last period plus what was bought less what was sold during this period. If the stockpile is of commercial value, then the price of a unit is non-zero and a strict equality holds.

Private stock minimum working level

pstklopeq(t,cstk).. stkprv(t,cstk)≥stklo(cstk)

Private stock maximum capacity level

pstkuppeq(t,cstk).. stkup(cstk)≥stkprv(t,cstk)

Sales from private stockpile arbitrage condition

qslp_arbeq(t,cstk)..pstk(t,cstk)≥ps(t,cstk)-ucts(cstk)

If the cost to sell from the private stockpile exceeds the price received on the domestic open market, adjusted for the cost of transporting to that market, then sales from the private stockpile will not occur. Otherwise, sales take place until the stockpile price rises to domestic market parity. Selling from the stockpile is a form of intertemporal trade, like contemporaneous spatial export trade. Inclusion of the transport cost to and from the domestic market stockpile allows separate determination of sales and purchases rather than just identifying change in the stockpile level.

Purchases for private stockpile arbitrage condition

qbyp_arbeq(t,cstk)..ps(t,cstk)+ucts(cstk)≥pstk(t,cstk)

If the cost to buy for the private stockpile exceeds the stockpile's per unit worth, then buying will not occur. Otherwise, purchases occur until the stockpile price falls to domestic market parity. From the above conditions, the private stockpile price differs from the domestic market price by at most twice the unit transport.

Private stockpiling intertemporal arbitrage condition

stkprv_arbeq(t,cstk)..pstk(t,cstk)+ucbs(cstk)+pstkupp(t,cstk)

-pstklop(t,cstk)≥pstk(t+1,cstk)/(1+r)

If the total cost of holding a unit in the private stockpile exceeds its unit benefit, then stock will not be held. Otherwise, stock will be held with the equilibrium found where the benefit of holding a unit over for the next time period (price of the stock deflated for deferred interest) equals the unit cost of doing so. The cost of holding over a unit in the stock is the asset's price in the stock today plus the unit operating and maintenance cost of holding it on plus a shadow tax to avoid holding stock in excess of maximum capacity less a shadow subsidy to avoid holding stock under a working minimum level of capacity.

Maximum capacity is imposed to ensure a unique solution under an exogenous world price setting and the minimum level is used for symmetry with the government stockpile conditions defined below.

In general, the intertemporal arbitrage condition for private stockpiling links commodity prices through time in a (discounted) price equalisation or smoothing fashion akin to spatial trade. Basically, if the underlying price level can change in response to demand and supply conditions, then if the price in this period is going to be higher than in the next period, the stockist will seize the profit opportunity to sell high until the discounted and adjusted equality holds, driving the price in this period down. Conversely, the stockist will buy low when the price is rising, until the discounted and adjusted equality holds. However, if the world price is given then stockholding behaviour does not generally smooth prices intertemporally unless the domestic price is within the autarky range so that prices are effectively determined locally. Free stockpile disposal is also assumed. Also it is noted that no terminal value condition is imposed here explicitly as the quantity limits provide a non-zero stock default closure at either the lower or upper bound.

Variable trade measures behaviour

Variable trade measures are included in the model as one set of instruments that can support a domestic price band policy for agristaples. Determining appropriate government setting of the levels for the ceiling and the floor may be critical issues. For example, the price floor could be set too high following a productivity breakthrough, or the price ceiling could be set too high in the face of a productivity slowdown, in each case constraining prices from signalling economically optimal resource reallocations. In what follows the floor and ceiling prices are exogenously set outside the model. However, running the model over a set of plausible price shocks with endogenous determination of the world price under free trade and with private stockholding may provide indicative limits for the price spread over time. In principle, this addresses efficiency concerns but distributional concerns may require the use of lump sum transfers.

Both the ceiling and floor rules apply to conditions where international trade is possible, not for autarky in agristaples, as indicated by the dollar conditionality on each of the equations. As previously noted, the producer price lies between the export parity and import parity bounds. In the absence of distortions, this band is twice the width of the unit transport cost to and from the world market.

Price ceiling rule

extxmsveq(t,cstk)$(1-dvaut)..pshi(cstk)≥ps(t,cstk)

Lowering the local price ps to the exogenous price ceiling pshi requires an export tax or the equivalent import subsidy depending on the trade direction. This measure appears in the export and import parity equations in the government accounts as appropriate. Otherwise, if the local price is lower than the price ceiling then no trade measure is required to support it.

Price floor rule

exsbmtveq(t,cstk)$(1-dvaut)..ps(t,cstk)≥pslo(cstk)

The price floor rule is symmetric to the price ceiling rule. Raising the local price ps to the exogenous price floor pslo requires an export subsidy or the equivalent import tariff depending on the trade direction. Otherwise, if the local price is higher than the price floor then no trade measure is required to support it.

Government stockpiling behaviour

As modelled, the domestic government's buffer stockpiling scheme is a hybrid scheme containing some features of private stockpiling and of the price band policy under variable trade measures described above. The equations are outlined below. In general, provided the stockpile has value, the private and government stock accumulation constraints are the same. The inequality constraints on the minimum and maximum stock capacities are also the same except the associated shadow prices differ when international trade is allowed. Only the government can support the stock limits with international trade using variable trade measures. In a trade regime, the government sells from the stockpile in an attempt to lower the local price until the working stock minimum is reached. In the small country case there is no effect on price as per private stockpiling. Hitting the minimum price level triggers the use of variable trade measures which are effective in achieving their exogenous price target band.

Government purchases follow symmetric triggers. The government buys for the stockpile in an attempt to raise the local price until maximum capacity is reached. This again triggers the use of variable trade measures. In the case of staples autarky, the government can directly influence the price through open market interventions. However, once the stock limit is reached that policy becomes ineffective and the price band is relaxed.

The government's behaviour in the model is not forward looking but works to an exogenous price band but this band as discussed previously can be informed by forward looking simulations of private stockists. It also follows that price band behaviour by the government whether through the government buffer stock described here or through variable trade measures effectively crowds out any economic incentive for private stockpiling.

It is also noted that in the model the price bands set for the government stockpile cover investment in sales and disinvestment by purchases only. Their settings ideally need to cover the costs of operating and maintaining the stockpile, transport costs between the stockpile and the local market, and interest forgone.

Government stock accumulation constraint

stkgoveq(t,cstk).. stkgov(t,cstk)=stk0(cstk)+sum(tt$(ord(tt) le ord(t)),

qbyg(tt,cstk)-qslg(tt,cstk))

The government stock on hand at the end of the current period is the initial opening stock in the first period plus cumulative net purchases for the stock during each of the periods to date.

The cumulative form used here is mathematically equivalent to stk0$tf(t)+stkgov(t-1,cst)+qbyg(t,cst)-qslg(t,cstk) but the cumulative form is computationally easier to work with.

Sales from government stockpile arbitrage condition

qslg_arbeq(t,cstk).. pshi(cstk)+pqslgup(t,cstk)$dvaut=n=ps(t,cstk)

If the domestic price is less than the price ceiling the government does nothing. Otherwise, it sells from the stock to the local open market in an attempt to lower the price to the price ceiling until the lower stock limit is hit (see below). In the case of agristaples autarky, once the stock limit is reached the price ceiling is abandoned and the price is market determined. Under a trade regime, hitting the stock limit triggers trade measures to reduce the price to the ceiling.

Note the symbol 'n' means that the equation holds exactly within the limits defined by the lower and upper bounds specified on the complementary variable. At the lower limit the inequality is positive and at the upper limit it is negative. Hence, when qslg is within its limits, qslg is endogenously determined by the rest of the model such that the price is set at the price ceiling; qslg is zero when pshi exceeds the price freely determined by the rest of the model; and qslg is at its upper bound when the price exceeds the ceiling. The symbol 'n' is needed to avoid redefinitions in the solution.

Purchases for government stockpile arbitrage condition

qbyg_arbeq(t,cstk)..ps(t,cstk)=n=pslo(cstk)-pqbygup (t,cstk)

Analogous with sales, if the domestic price is more than the price floor the government does nothing. Otherwise, buy low from the domestic market for the stock in an attempt to raise the price to the price floor until the upper stock limit is hit. In the case of agristaples autarky, once the stock limit is reached the price floor is abandoned and the price is market determined. Under a trade regime, hitting the stock limit triggers trade measures to increase the price to the floor.

Note when qbyg is within its limits, qbyg is endogenously determined by the rest of the model such that price is set at the price floor; qbyg is zero when pslo is below the price freely determined by the rest of the model; and qbyg is at its upper bound when the price falls short of the targeted floor price.

Government stock minimum working level/upper limit on sales

pqslgupeq(t,cstk)..stk0(cstk)+sum(tt$(ord(tt) le ord(t)-1),

qbyg(tt,cstk)-qslg(tt,cstk))-stklo(cstk)≥qslg(t,cstk)

As described above, a minimum stock limit is enforced by stopping selling from the stock. This is imposed for computational ease as an upper limit on sales from the stock: qslgup(t,cstk)≥qslg(t,cstk) where qslgup is the left hand side of the above expression. This follows from stkgov(t,cstk)≥stklo(cstk) when qbyg(t,cstk) is zero under upward price pressure.

Once sales hit the upper limit, this leads to easing of the price ceiling rule under autarky to preserve feasibility or triggers a variable trade measure in the form of an export tax/import subsidy to support the price ceiling under a trade regime.

Government stock maximum capacity level/upper limit on purchases

pqbygupeq(t,cstk).. stkup(cstk)-stk0(cstk)-sum(tt$(ord(tt) le ord(t)-1),

qbyg(tt,cstk)-qslg(tt,cstk))≥qbyg(t,cstk)

Symmetrically, a maximum stock limit is enforced by stopping buying for the stock. This is imposed for computational ease as an upper limit on purchases for the stock: qbygup(t,cstk)≥qbyg(t,cstk) where qbygup is the left hand side of the above expression. This follows from stkup(t,cstk)≥stkgov(cstk) when qslg(t,cstk) is zero under downward price pressure.

Once purchases hit the upper limit, this leads to easing of the price floor rule under autarky or triggers a variable trade measure in the form of an export subsidy/import tariff to support the price floor under a trade regime.

Export tax import subsidy trigger

extxmsgeq(t,cstk)$(1-dvaut)..pshi(cstk)+tiny≥ps(t,cstk)

If trade is possible under the hybrid policy regime, the government may resort to an export tax or import subsidy to lower the local price once no longer able to sell product from the stockpile. This expression is the same as for the variable trade price band except for the inclusion of the exogenous term tiny. Setting tiny to 1.0e-06 ensures that the trade measure is only triggered when the sales limit is reached.

Export subsidy import tariff trigger

exsbmtgeq(t,cstk)$(1-dvaut)..ps(t,cstk)≥pslo(cstk)-tiny

Symmetrically, if trade is possible under the hybrid policy regime, the government may resort to an export subsidy or import tariff to raise the local price once no longer able to buy product for the stockpile. Again, this expression is the same as for the variable trade price band policy.

9 Module of consumer subsidy as ration coupons for agristaples

The purpose of this module is to address significant changes in agristaple prices through the distribution of consumer rations.

There are minimum nutritional requirements to support a healthy life. This modelling exercise does not attempt to measure the damages that arise when these food requirements are not met. However, a measure of food surplus to minimum requirements is represented in the model output for each household group by:

sum(c, cfac(c)*qdchbar(t,c,hh))-sum(c, cfac(c)*qdch(t,c,hh))

The first term represents normal requirements for agristaples over time for each of the aggregate household groups modelled when there are no staple food shocks or general changes to related policies. The second term represents conditions that are simulated to prevail under alternate policy regimes and staple food shocks. If this food surplus turns negative there is cause for concern and at least further investigation of the model results. Note that cfac is the conversion factor that takes the quantity of a commodity consumed and converts it into its rice equivalent. Quantity measures here are the number of units that are purchased out of the expenditure by the relevant household group in aggregate using base year prices.

Three options are considered in the model in an attempt to directly address consumer food security. They are all examples of tradable coupon (food stamp) entitlements that could be administered by the government. At the start of the year the government could announce the terms for this year's annual subsidized purchases of staples by a household. For example, the terms might read any time this year you buy one kg of wheat or rice at any market then you are entitled to use the debit card to pay for an extra y of a kg, up to an annual limit of z kilograms in all as total debits, where fractional purchases are allowed. These arrangements involve market based provision of agristaples with government involvement in payment.

A coupon, as defined here, is a specific consumer subsidy with a fixed annual ration limit per household. Ideally, the definition of household should target nutritional needs, purchasing power and family vulnerabilities.

In principle, the use of consumer subsidies should be designed to deliver the best value. This suggests the provision of the coupon should be targeted to the lowest income earners where income shares on agristaples are largest. However an issue with this is identifying people in this group and ensuring that the policy does not induce a poverty trap. For this reason, an alternative to consider is to have a generic coupon that is available to all households regardless of economic circumstances. A further economic extension of this is to allow coupons to be traded between all households. In this way they would be purchased by those that value them the most. If this was simply a matter of price elasticity of demand then this would suggest that this would ensure that low income earners would buy entitlements if trade is allowed.

However, of most concern is purchasing power, and those with low incomes are least able to pay for food staples. This might suggest that low income earners would sell entitlements if trade is allowed. The government could always over supply this group in order that the moneys earned, provide an effective cash transfer, so that they could pay for commodities they need more generally on the open market.

It is important to note that the representative household concept in the model is real GDP per aggregate household group, where the groups are defined by main occupational status. For simplicity, household shares in factor ownership and in discretionary consumer expenditure by commodity are constant over the model's time horizon. These features mean that the consumer subsidy option can be modelled by alternative quota schemes as follows.

Targeted low income groups, total quota/consumer subsidy condition

pcsublneq(t,hhli)..sum(c, cfac(c)*qdch(t,c,hhli))

≥sum(c,cfac(c)*qdchbar(t,c,hhli))

For each of the low income aggregate household groups, if they are able to consume more than their ration under open market conditions then the subsidy is not required. Otherwise, income is deficient to support food security and the debit card is triggered to provide the support needed where pcsubln is the implied rate of specific subsidy/coupon price for low income earners.

Expenditure on the subsidy entitlements appears in the government's expenditure account and the consumer price for the commodity in the market is replaced by the consumer price net of the subsidy in the household group demand function (see below). The coupons are tradable between the low income groups here on the grounds that they will end up being held by those who value them the most within the constraint that all households are low income groups.

Untargeted generic, total quota/consumer subsidy condition

pcsubaneq(t,hh)..sum(c, cfac(c)*qdch(t,c,hh))

≥sum(c, cfac(c)*qdchbar(t,c,hh))

This is analogous to the targeted consumer subsidy, except that now each and every household group gets its own quota (coupon entitlement) and there is a potentially different rate of implicit subsidy, coupon price for each group.

Untargeted generic total traded quota/consumer subsidy condition

pcsubateq(t)..sum((c,hh),cfac(c)*qdch(t,c,hh))

≥sum((c,hh),cfac(c)*qdchbar(t,c,hh))

Under this tradable coupon arrangement, everyone gets an entitlement but with tradability there is one specific implied rate of subsidy or coupon price.

10 Model of commodity production by industry

In the model, each industry produces a single good that is specific to that industry. Output is produced according to constant returns to scale technology. The exact level of output produced is determined from the rest of the model. The representative perfectly competitive firm that represents the industry in aggregate chooses the level of inputs to minimise total annual costs of production, taking as given the required output level, and input and output prices. In particular, the output technology is Leontief between intermediate inputs and value added. Since output is measured in the same units as value added, the level of output also represents value added. In turn, value added is a CES function defined over relevant primary factor inputs (Figure 1).

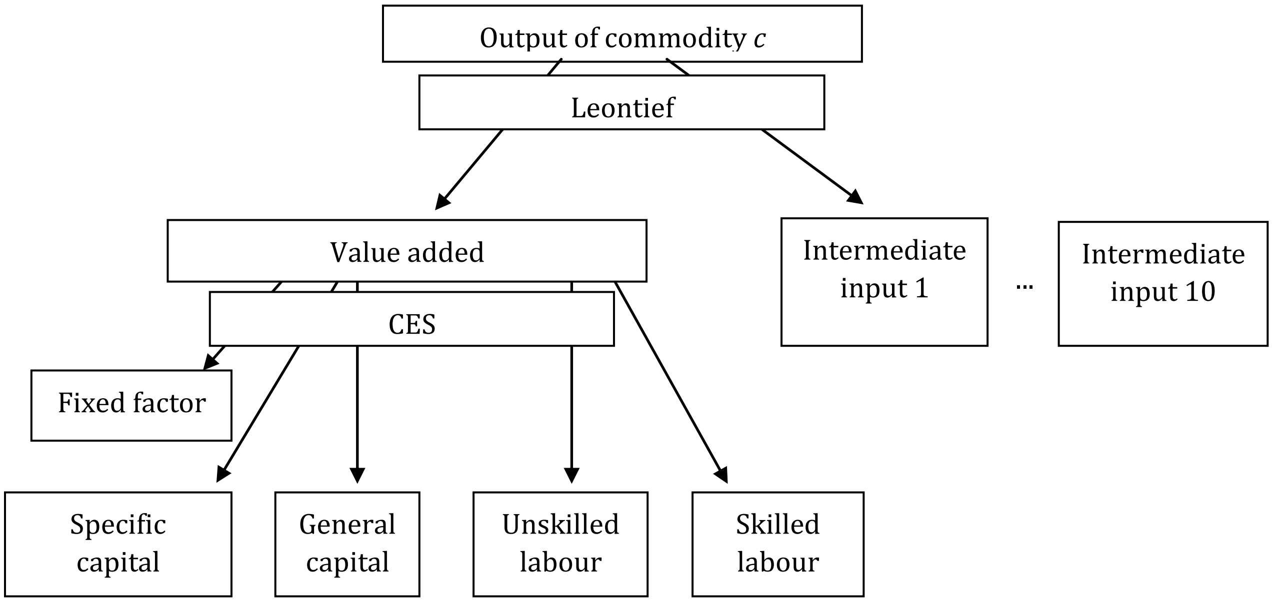
Autonomous technological change is included for each input.

The resulting equations for this system are shown below. In these equations the optimization problem is broken into two parts: First, choose the level of output to maximize profit. Second, given the level of output, choose the level of primary factor demands to minimize the total cost of value added.

In the first part, profit is calculated as revenue less total cost (all costs are variable). Total cost is the cost of value added plus the cost of intermediate input use. Two things must be substituted into the profit expression: the level of output which is the level of value added and the amount of intermediate input use which is in fixed proportions to the level of output. From this new profit expression, the level of production must be cancelled out. In so doing it should now be recognised that an equilibrium solution on competitive markets profit is ≤ 0. If profit is <0 then production is nil; otherwise profit=0 at a solution. This gives equation qs_arbeq below. The fixed proportions demand for intermediate goods appears in equation qdint_foceq, which is the aggregate demand for a commodity as an intermediate good.

In the second part of the optimization problem, the total cost of value added is a CES unit cost function, defined over primary factors prices and multiplied by the level of output. The unit cost function is given in equation pva_dfeq below. Primary factor demands, fdg_foceq, follow using Shephard's lemma.

Figure 1 Production structure of the model



Note some primary inputs are industry specific while others are general factors that are mobile across industries, commanding an economy wide wage or rental price. In particular, each of the primary industries includes an industry specific "fixed factor". This is a land resource in exogenous supply in each of the agricultural industries. The specific fixed factor in the mining, forestry and fishing sector is a natural resource in exogenous supply. The existence of an industry-specific fixed factor induces an upward slope to each primary industry supply curve, reducing the tendency for the economy's primary enterprises to specialise in one least-cost production activity. All the industries use general capital and unskilled labour. Only industries that are mobile ("footloose"), namely the manufacturing and service industries, have industry-specific capital. Skilled labour is specialised in the sense that it is required by non-agricultural industries but is mobile across these industries. Supplies of both labour types are exogenously determined.

Price cost arbitrage condition for production

qs_arbeq(t,c).. pva(t,c)+sum(c2,tcioi(t,c2,c)*io0(c2,c)*

pd(t,c2))≥ps(t,c)*(1-txps(c))

In the price cost arbitrage equation for production, the firm will not engage in production if the unit cost of production exceeds the price received, provided any adjustments for an existing production tax has been made in the baseline database. Otherwise, the firm will produce until the marginal net benefit (unit cost minus price benefit) from production is driven to zero and the total net benefit is maximised. The unit cost of production is the price of value added (the cost of primary inputs required to make a unit of output) plus the unit cost of intermediate inputs (the cost of intermediate inputs required to make a unit of output).

Note that if there is a technical advance in intermediate factor use of X per cent, then the index tcioi falls by X per cent, as less input is required to make a unit of output. In addition to reducing effective primary input use, an agristaple domestic cost fall (rise) of X per cent reduces (increases) tcioi by X per cent.

CES price function for value added

pva_dfeq(t,c)..(pva(t,c)/pva0(c))**(1-sigmapva(c))=

sum(fg$dvfacg(fg,c),alphag(fg,c)*

(faugtcgi(t,fg,c)*(wfg(t,fg)/wfg0(fg)))**(1-sigmapva(c)))

The CES function for value added is expressed in scaled form. This may be seen by inserting the first order condition for a primary factor input (given below) into the right hand side of the following definition for value added:

pva*va=sum(fg$dvfacg(fg,c),wf(fg)*fd(fg,c))

Note that alphag is the base year value of the primary factor input cost in the total cost of value added, where dvfacg conditions the set of industry inputs to those used in the database for the base year.

In log differential form, the growth in the price of value added is a base-year cost share-weighted sum of the factor input prices, and the rates of exogenous factor-augmenting technical change, where X per cent progress is represented as a negative fractional rate of -0.X. In other words, if there is a technical advance (regress) in primary factor use of X per cent, then the index faugtcgi falls (rises) by X per cent. A domestic cost fall (rise) of X per cent, for example for an agristaple, reduces (increases) faugtcgi by X per cent.

First order condition for primary factor input demand

fdg_foceq(t,fg,c)$dvfacg(fg,c).. (fdg(t,fg,c)/fdg0(fg,c))=

faugtcgi(t,fg,c)*(qs(t,c)/qs0(c))*

((pva(t,c)/pva0(c))/(faugtcgi(t,fg,c)*

(wfg(t,fg)/wfg0(fg))))**sigmapva(c)

From the first order condition above, it can be seen that growth in the demand for a factor equals the fractional rate of technical change (negative for an advance) plus the rate of output growth plus the sigma weighted value of the growth rate in the price of value added less the growth rate in the factor price less the fractional rate of technical change. It follows that a 1 per cent increase in output increases the demand for the primary factor by 1 per cent, other things equal. Further, given the percentage change form for the price of value added, a technical advance of -X per cent (or fractional rate -0.X) yields an X per cent reduction in the requirement for that input in the production process. If all factors experience this same advance (Hicks neutral) then the unit output cost falls by X per cent overall, or the unit cost is unchanged and the same amount of output is produced with X per cent less of each input.

Aggregate demand for good c as an intermediate good

qdint_foceq(t,c2)..qdint(t,c2)=sum(c,io0(c2,c)*tcioi(t,c2,c)*qs(t,c))

The variable qdint is a useful aggregate of economy-wide material input requirements by industries for each commodity. It reflects the Leontief nature of demand for intermediate goods in industry production processes.

11 Module of domestic end user incomes

Household group nominal factor income definition

yfhg_dfeq(t,hh,fg)..yfhg(t,hh,fg)=shryg(hh,fg)*

sum(c,wfg(t,fg)*fdg(t,fg,c))

The household group's income by factor is the fixed ownership share of the factor's rents (or wages) earned in all industries where it is used. The share is taken from the base year data.

Total household nominal income definition

yh_dfeq(t,hh).. yh(t,hh)=sum(fg,yfhg(t,hh,fg))

Total household group income is the sum of all factor incomes earned. There are no transfers to households from governments or other agents in the model's database.

Government nominal revenue definition

grev_dfeq(t)..grev(t)={sum(c,txmt(t,c)*qm(t,c)*(pwn(t,c)+utc(c)))*exr(t)+

sum(c,txet(t,c)*qe(t,c)*(pwn(t,c)-utc(c)))*exr(t)+ sum(c,txps(c)*ps(t,c)*qs(t,c))+

sum(hh,htax(t,hh)*yh(t,hh))+sum(c,txpd(c)*ps(t,c)*(qdc(t,c)+qdint(t,c)+qdinv(t,c)

+qdgov(t,c)))}+

{sum(cstk,(extxmsv(t,cstk)-exsbmtv(t,cstk)+extxmsg(t,cstk)-

exsbmtg(t,cstk))* qe(t,cstk)*(pwn(t,cstk)-utc(cstk)))*exr(t) +

sum(cstk,(exsbmtv(t,cstk)-

extxmsv(t,cstk)+exsbmtg(t,cstk)-extxmsg(t,cstk))*

qm(t,cstk)*(pwn(t,cstk)+utc(cstk)))*exr(t)}-

{sum(c,cfac(c)*(sum(hhli,pcsubln(t,hhli)*qdchbar(t,c,hhli))+

sum(hh,pcsuban(t,hh)*qdchbar(t,c,hh))+ sum(hh,pcsubat(t)*qdchbar(t,c,hh))))}

Government revenue comprises standard and non-standard terms. The standard term is the first term in brackets. This is the sum of import tariff, export tax, output tax, income tax and sales taxes in the base year database. Note that the output (production) and sales (consumption) taxes are constructed in a way that readily verifies Lerner's symmetry theorem on the equivalence of standard trade measures with combined production and consumption instruments.

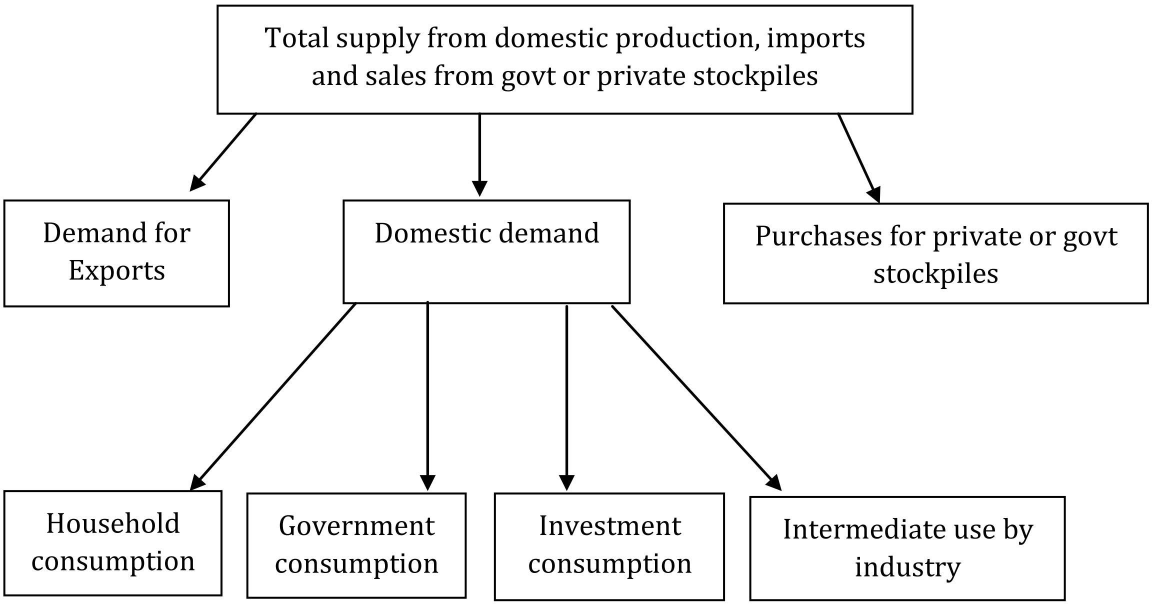
The second term in brackets accounts for non-standard trade measures arising under the variable trade domestic price band policy and the related behaviour triggered under government stockpiling to support a price band when stock limits are reached. The last term in brackets comprises the consumer subsidy payments for coupon entitlements/quota limits evaluated at the implicit subsidy/coupon price. The modules detailing the agriculture specific policies for price stability and for variable agristaples consumer subsidies with quota coupons are described in sections 8 and 9.

12 Module of domestic end user incomes

In general in the model, commodities are sold to foreign exporters and sold for domestic use by households, government (direct use), capital creators (for investment) and firms as intermediate inputs (see Figure 2). Some goods are not used in capital creation from the base year database. All commodities can be traded internationally, and in the perfect substitutes model used here, product is either exported, not traded or imported, depending on economic profitability. In general, the sources of supply to the domestic market comprises local and imported product. For agristaples only, purchases and sales by government or private stockpilers are modelled explicitly in the model. (The equation for the domestic market balance is given in the market balance module below.)

The purpose in this module is to describe household, government and investment consumption.

Figure 2 Types of domestic demand



Real private household group consumption of commodity behaviour

qdch_foceq(t,c,hh)..

(pd(t,c)-(cfac(c)*(pcsubln(t,hh)$hhli(hh)+

pcsuban(t,hh)+pcsubat(t)))$cfac(c))*qdch(t,c,hh)=

(pd(t,c)-(cfac(c)*(pcsubln(t,hh)$hhli(hh)+

pcsuban(t,hh)+pcsubat(t)))$cfac(c))*cmin(t,c,hh)+

cles(c,hh)*((1-mps(hh))*(1-htax(t,hh))*yh(t,hh)-

sum(c2, (pd(t,c2)-(cfac(c2)*(pcsubln(t,hh)$hhli(hh)+

pcsuban(t,hh)+pcsubat(t)))$cfac(c2))*cmin(t,c2,hh)))

This equation above is the first order condition for household consumption of a commodity derived by maximising a Stone Geary utility function subject to an annual income budget constraint on total nominal consumption expenditure. It is the demand function for a commodity in the linear expenditure system. It is most readily recognised as such by setting cfac to zero, in which case the equation reads:

pd(t,c)*qdch(t,c,hh)=pd(t,c)*cmin(t,c,hh)+cles(c,hh)*

((1-mps(hh))*(1-htax(t,hh))*yh(t,hh)-sum(c2,pd(t,c2)*cmin(t,c2,hh)))

This simpler expression becomes the following expression when pd(t,c) is replaced by the price net of the relevant consumer subsidy term, that is:

pd(t,c)-(cfac(c)*(pcsubln(t,hh)$hhli(hh)+

pcsuban(t,hh)+pcsubat(t)))$cfac(c)

The consumer subsidy is only paid on goods which contribute to the ration quota at per unit rate cfac per quantity volume. There are three rates of subsidy per household group, only one or none of which applies depending on the simulation.

Returning to the simpler expression where cfac is zero. If cmin, the minimum necessary consumption of the household group on the commodity, is set to zero then this collapses to the first order condition for demand using a Cobb-Douglas utility function. In that case, spending on the commodity is a constant share of available income after household taxes and savings, where each of these totals is in turn represented as a fraction of income. Expressions for household savings and household tax payments are given in the investment saving balance described below (along with some related points on model closure) and in the earlier government revenue expression.

When cmin is non-zero, spending on the commodity in excess of minimum requirements looks to be in a Cobb-Douglas structural form, in that it is a constant share of income in excess of minimum expenditure requirements. Note that as part of the baseline assumptions, cmin increases exogenously over time from its initial database value.

Total real private consumption of commodity definition

qdc_dfeq(t,c).. qdc(t,c)=sum(hh,qdch(t,c,hh))

Total real consumption of a commodity is the aggregate of all household group uses.

Price cost arbitrage condition for capital good creation

is_arbeq(t)..sum(c,pd(t,c)*ioinv(c)*iadj(t))≥pi(t)

In the model there is one type of capital that is created for all capital uses (how capital is allocated across industries and across time is explained below). The capital good is created using a Leontief production technology defined over commodity inputs used for real investment expenditure in the base year. The base year input-output coefficients by commodity are adjusted over time by a common technical advance term in capital creation. This works to equalise aggregate savings and nominal investment expenditure (see below).

In this equation, akin to commodity production, the capital is not created if the unit cost exceeds the price received. Otherwise the production level is positive, at a level determined in the rest of the model, requiring price to equal unit cost.

First order condition on real investment expenditure

qdinv_foceq(t,c)..qdinv(t,c)=ioinv(c)*iadj(t)*is(t)

This is the demand for a commodity, or real investment expenditure, used in capital creation.

First order condition real government expenditure on a commodity

qdgov_foceq(t,c)..qdgov(t,c)/qdgov0(c)=gadji(t)

This is the base year scaled form of the government's demand for a commodity. It is derived by minimizing the annual cost of government expenditures subject to a Leontief technology defined over commodities used by government in the base year, where gadji(t) is the exogenous index of real government expenditure which grows at a baseline rate of gfac. It is analogous to the first order condition on real investment expenditure, when iadj is equal to one and that equation is divided by qdinv0.

Total nominal government expenditure definition

gexp_dfeq(t)..gexp(t)=sum(c,pd(t,c)*qdgov(t,c))

Total nominal government expenditure is the sum of all government purchases on all commodities. There are no transfers to households and foreigners in the model's database.

13 Module of market balances

Local consumer price market balance condition

pd_equilnmeq(t,c)..

{(qs(t,c)+qm(t,c))$cnexch(c)}+(pd(t,c)*cwts(c))$cexch(c)=

{((qdint(t,c)+qdc(t,c)+qdgov(t,c)+qdinv(t,c))+qe(t,c))$cnexch(c)+

(qbyp(t,'cwhet')-qslp(t,'cwhet')+qbyg(t,'cwhet')-

qslg(t,'cwhet'))$c_whet(c)}+

(cpi-sum(cnexch,pd(t,cnexch)*cwts(cnexch)))$cexch(c)

The local consumer price market balance condition comprises two types of equations. The first type of equation applies for all 'no exchange' goods, which are elements in cnexch (the meaning of exchange is explained shortly). For these goods, and in the standard case, the balance condition is part of the model system. In the balance condition, supply available on the local market (equivalent to domestic production plus imports) equals aggregate demand on the local market. Aggregate demand is calculated as the sum of individual domestic demands by industries, households, government, and in capital creation as well as export demand. These terms are in brackets in the equation. The non-standard case includes additional terms for the commodity wheat. For wheat and rice, stockpiling of government or private agents is considered, where buying decreases and selling increases supplies available on the local market.

The second type of equation is a condition defining the cpi. This equation applies for cexch, which is the commodity rice in this version of the model. The cpi is the unit price for the numeraire good chosen to close the model. The cpi is an exogenous constant price, set at its base year value, All the prices in the model are real and expressed relative to the price for a unit of the base year consumption basket.

Homogeneity check

In principle, the choice of the numeraire has no bearing on real quantity variables, as only relative prices matter (there is no money illusion). Doubling the cpi should have no impact on real variables in model simulations; it serves as a homogeneity check. To satisfy this condition it is necessary to multiply exogenous price band limits by the quotient of the new value of the exogenous cpi and the old value for the exogenous cpi. This must also be done for the exogenous unit cost of transport to and from storage silos, and for the direct unit cost of storage for agristaples.

Check of Walras law

In order to check that Walras law holds, the approach taken is to exchange the balance condition for rice for the numeraire price condition, and then to test if the balance holds for rice. This can be done as follows.

walras_equilnmeq(t).. walras(t)=sum(cexch,qs(t,cexch)+qm(t,cexch)-

qdint(t,cexch)-qdc(t,cexch)-qdgov(t,cexch)-qdinv(t,cexch)-qe(t,cexch)-

(qbyp(t,'crice')-qslp(t,'crice')+qbyg(t,'crice')-qslg(t,'crice'))

The variable walras appears nowhere else in the model and should be zero at a valid solution. This is a necessary but not sufficient check of a valid model solution. It is the excess supply of rice on the local market with terms as previously explained.

Local factor market balance condition

wfg_equileq(t,fg)..fsg(t,fg)$fgncap(fg)+capgn(t)$fggn(fg)+

capsp(t,fg)$fgsp(fg)≥sum(c,fdg(t,fg,c))

The total supply of a factor is greater than or equal to the aggregate demand for it in the industries where it is used. If there is excess supply, then the rental price of the factor (the factor wage) is driven to zero. Otherwise, the market clears and resources are drawn to industries until the rental price equalises with the marginal benefit in each use.

In the model, the supply of labour, land and other natural resources are exogenous. The supply of capital is endogenously determined. In particular, general capital is mobile across sectors while specific capital is industry specific. For details of the link between capital supply and capital investment, see below.

Foreign exchange current account balance definition

The current account balance is expressed in foreign (world) currency. The supply of foreign exchange, from export payment by the rest of world (row) and from rest of world (row) savings equals the domestic demand for foreign exchange to pay for imports from the rest of world (row). Foreign savings increase at the baseline growth rate under the closure used for the simulations.

exr_cabaleq(t)..sum(c, (pwn(t,c)-utc(c))*qe(t,c))+fsav(t)=

sum(c, (pwn(t,c)+utc(c))*qm(t,c))

Savings investment balance

This following equation is used to reconcile the annual supply of savings funds (income not spent consuming current commodities) with annual demand for these funds (expenditures on commodities for capital creation used to make commodities in the future).

iadj_savinvbaleq(t)..sum(hh,mps(hh)*yh(t,hh)*(1-htax(t,hh)))+

grev(t)-gexp(t)+fsav(t)*exr(t)=sum(c,pd(t,c)*qdinv(t,c))+

{sum(cstk,ps(t,cstk)*(qbyp(t,cstk)-qslp(t,cstk)))+

sum(cstk,ps(t,cstk)*(qbyg(t,cstk)-qslg(t,cstk)))}

The left hand side of this expression is aggregate savings (the sum of household, government and foreign saving) to source domestic investment expenditures (the right hand side). The latter covers investment in physical capital (new capacity) and in changes in the stockpiles of agristaples.

Capital does not depreciate in the model but is kept intact with regular maintenance.

A note on model closure

Because the real rate of interest is constant and exogenous in the model, the supply and demand for investment funds are reconciled by endogenising iadj, which is the annual rate of technical advance in capital creation (also see is_arbeq and qdinv_foceq). This is analogous to a model closure option in the comparative static version of the standard IFPRI model (see Lofgren et al. 2002).

Other closures are possible, such as endogenising the marginal propensity to save by one household type. Government saving also changes endogenously but the feedback is not sufficient to balance aggregate savings and investment without endogenising the household tax rate. Since this acts like a lump sum transfer, it would have an equivalent effect given real government revenue is exogenous. To ensure the model simulates sustainable long term conditions, it is assumed that the trade balance is kept constant in foreign currency terms, that is, foreign saving is exogenous. These conditions ensure debt is not allowed to increase to unsustainable levels.

Alternatively, intertemporal consumption smoothing by household groups could be modelled at the cost of additional complexity. In the current version of the model, only investors in physical capital used by industries and private agristaples stockpilers have forward-looking behaviour (see below for further details). Their expectations of future asset prices are held with perfect foresight. The behaviour of all other agents is myopic, depending on current conditions only.

Local capital good market balance condition

pi_ibaleq(t)..is(t)=idgn(t)+sum(fgsp,idsp(t,fgsp))

The supply of new physical capital, from the capital creation sector, balances its uses as capital additions in the general capital rental sector and as installed immobile capital additions in specific industries. As modelled, one type of capital is created by the capital creation sector. Its nature is only decided once its use as general rentable capital or as immobile sector specific capital is selected. This is consistent with various models which assume that capital is like putty from the creation side that only becomes clay once installed in a specific sector (see the discussion in Dixon, Parmenter and Wilcoxen 1992).

14 Module for capital good accumulation and consumption

Physical investment in general capital, is made to maximise the net present value of intertemporal profits derived from that capital subject to a capital stock accumulation constraint. The objective function is

sum(t,dr(t)*(wfg(t,'ffcapt')*capgn(t)-

pi(t)*idgn(t)*(1+gammagn*idgn(t)/capgn(t)))

where dr(t)=1/(1+r)**(ord(t)-1).

The annual return is the rental cost of capital used across industries. The annual cost is the cost of purchasing and installing new capacity to meet market requirements. The stronger is the capacity expansion relative to the level of existing capacity, the larger are investment costs in new capacity installed. As a consequence, in the model there can be an anticipatory increase in capital to avoid high adjustment costs. This occurs in the model in addition to the fact that capital additions are assumed to take one period to install following the single period in which additions are created. In particular, the general capital stock constraint, measured at the end of the period, is as follows.

General physical capital accumulation condition

capgn_accumeq(t)..capgn(t-1)+idgn(t-1)+capgn0$tf(t)=capgn(t)

To ease the solution, this is expressed in equivalent form

capgn_accumeq(t)..capgn0+

sum(tt$(ord(tt) le ord(t)-1),idgn(tt))=capgn(t)

The level of general physical capital available for rental throughout the economy is the cumulative sum of capacity additions made to date over the model horizon, taking into account a one period installation lag and the existence of an inherited amount of capital available from the first period.

The Lagrangian problem is maximized with respect to the investment level and a shadow asset price condition, for the dual price associated with the capital stock, may also be derived.

Price cost arbitrage condition for investment in general capital –initial version

idgn_arbeq(t).. pi(t)*(1+gammagn*idgn(t)/capgn(t))≥pcapgn(t+1)/(1+r)+

(pcapgn(t)/(1+r))$tl(t)

This equation is derived directly from the optimisation problem. The marginal cost of investment in new general capital is greater than or equal to its marginal benefit. The latter is the price of the asset next period deflated by interest (to account for the time delay). If it is profitable to invest, then this occurs until the marginal net benefit is zero. Note that the last term adds a terminal condition that the asset price one period post terminal is the price in the terminal year.

General physical capital, intertemporal asset price rule – substituted out with additional assumption

pcapgn_accumeq(t)..

pcapgn(t)=pcapgn(t+1)/(1+r)+(pcapgn(t)/(1+r))$tl(t)+

wfg(t,'ffcapt')+0.5*gammagn*pi(t)*(idgn(t)/capgn(t))*(idgn(t)/capgn(t))

The asset value of holding a unit of general capital in the stock this period is the asset value of a unit next period deflated for interest delay plus the unit benefit received for renting it out this period plus the benefit from extra investment adjustment costs avoided.

To ease the solution the expression for pcapgn was substituted into idgn_arbeq, as follows.

Price cost arbitrage condition for investment in general capital – final version

idgn_arbeq(t).. dr(t)*pi(t)*(1+gammagn*(idgn(t)/capgn(t)))≥

sum(tt$(ord(tt) ge ord(t)+1),

dr(tt)*(wfg(tt,'ffcapt')+0.5*gammagn*pi(tt)*(idgn(tt)/capgn(tt))*

(idgn(tt)/capgn(tt))))+sum(tl,dr(tl)*(wfg(tl,'ffcapt')+

0.5*gammagn*pi(tl)*(idgn(tl)/capgn(tl))*(idgn(tl)/capgn(tl))))/r

The terminal condition is more restrictive in this case. It is assumed that the capital asset price is constant from the terminal year rather than just assuming that the one period post terminal asset price equals the price in the terminal year. The more restrictive form is also used in Conrad (1999).

The decisions and expressions governing investment in specific physical capital are analogous to their general physical counter parts and are described mathematically as follows without further explanation.

Industry specific physical capital accumulation condition

capsp_accumeq(t,fgsp)..capsp(t-1,fgsp)+idsp(t-1,fgsp)+capsp0(fgsp)$tf(t)=

capsp(t,fgsp)

As discussed, to ease the solution, this is expressed in equivalent form:

capsp_accumeq(t,fgsp)..capsp0(fgsp)+

sum(tt$(ord(tt) le ord(t)-1),idsp(tt,fgsp))=capsp(t,fgsp)

Price cost arbitrage condition for investment in industry specific capital-initial version

idsp_arbeq(t,fgsp)..pi(t)*

(1+gammasp(fgsp)*idsp(t,fgsp)/capsp(t,fgsp))≥

pcapsp(t+1,fgsp)/(1+r)+(pcapsp(t,fgsp)/(1+r))$tl(t)

Industry specific physical capital, intertemporal asset price rule- substituted out with additional assumption

pcapsp_accumeq(t,fgsp)..pcapsp(t,fgsp)=pcapsp(t+1,fgsp)/(1+r)+

(pcapsp(t,fgsp)/(1+r))$tl(t)+wfg(t,fgsp)+0.5*gammasp(fgsp)*pi(t)*

(idsp(t,fgsp)/capsp(t,fgsp))*(idsp(t,fgsp)/capsp(t,fgsp))

To simplify the solution, the expression for pcapsp was substituted into idsp_arbeq, as follows.

Price cost arbitrage condition for investment in industry specific capital-final version

idsp_arbeq(t,fgsp)..

dr(t)*pi(t)*(1+gammasp(fgsp)*(idsp(t,fgsp)/capsp(t,fgsp)))≥

sum(tt$(ord(tt) ge ord(t)+1),

dr(tt)*(wfg(tt,fgsp)+0.5*gammasp(fgsp)*pi(tt)*(idsp(tt,fgsp)/

capsp(tt,fgsp))*(idsp(tt,fgsp)/capsp(tt,fgsp))))+

sum(tl,

dr(tl)*(wfg(tl,fgsp)+0.5*gammasp(fgsp)*pi(tl)*(idsp(tl,fgsp)/

capsp(tl,fgsp))*(idsp(tl,fgsp)/capsp(tl,fgsp))))/r

15 Scenario environments

The model is designed to simulate a range of economic environments, including a baseline. The scenarios, as they are currently set up, focus on policies related to agristaples.

In the simulation report the three simulation settings are business as usual (BAU), full liberalisation with removal of domestic agristaples policy and trade liberalisation of agristaples and food processing (FLIB) and trade liberalisation only (TLIB) (Table 2 and refer to main report). For any given simulation setting, any of the following environments can be chosen:

- a world price environment (wpe)
- a general policy environment (gnpole)
- a specific agristaples environment (sppole)
- a consumer agristaples policy environment (cpole), and
- an agristaples shock environment (shke).

The simulation settings used in the body of the current report are given in **Error! Reference ource not found.**.

Table 2 Scenario settings for the report

Scenario	wpe	gnpole	sppole	cpole	shke
BAU	lc	bas	gstk	csubexg	duppmt
					ddnpmt
					ruppmt
					rdnpmt
FLIB	lc	ftr	nspec	nocsub	duppmt
					ddnpmt
					ruppmt
					rdnpmt
TLIB	lc	ftr	gstk	csubexg	duppmt
					ddnpmt
					ruppmt
					rdnpmt

Environment settings

The following definitions allow the user to specify their desired environment.

Set name	Environment setting and set contents	
wpe	world price assumption for agristaples	
	/sc	small country
	lc	large country/

gnpole	general policy environment for agristaples	
	/bas	base trade policy as per model database
	ftr	free trade policy in specific commodity markets
	aut	autarky in agristaples/
sppole	special policy environment for agristaples	
	/nspec	no special policy
	vtpb	variable trade measures to support local price band
	gstk	hybrid government stockpile to support local price band
	pstk	private stockpiling/
cpole	consumer subsidy environment for agristaples	
	/nocsub	no consumer subsidy
	csubln	targeted minimum consumption quota
	csubaln	non-tradable untargeted minimum consumption quota
	csubalt	tradable targeted minimum consumption quota
	csubexg	existing fixed price consumption quota
shke	agristaples shock environment	
	/nshk	no shock
	duppmt	domestic costs up permanently from negative technology shocks
	duptmp	domestic costs up temporarily from negative technology shocks
	ddnpmt	domestic costs down permanently from positive technology shocks
	ddntmp	domestic costs down temporarily from positive technology shocks
	ruppmt	world price/ row costs up permanently from negative technology shocks

ruptmp	world price/ row costs up temporarily from negative technology shocks
rdnpmt	world price/ row costs down permanently from positive technology shocks
rdntmp	world price/ row costs down temporarily from positive technology shocks/

16 Unbalanced growth path extension

The model was initially calibrated to a baseline path with balanced economic growth. All quantity variables increased at a constant fractional rate, gfac, including

- real primary factor payments
- real GDP
- consumption expenditure
- foreign saving, and
- base-year physical investment to capital ratios.

Demand and supply shifters in foreign demand and supply curves were adjusted to maintain the common rate of domestic demand and supply expansion for agristaples given the assumption of constant real price path.

All exogenous primary factors of production (labour, land, minerals, forestry and fishery resources) were also set to grow at rate gfac. In the balanced growth simulation, this is most simply modelled as a direct increase in available annual total supply of gfac. An alternative assumption (but perfectly equivalent assumption in terms of model simulation outcomes) is that exogenous total supply of each exogenous primary factor grows at the fractional rate z(fg) and that technical advance in all production processes is

(gfac-z(fg))/(1+z(fg)).

This baseline path was necessary for testing model performance and, more generally, for conducting counterfactual experiments which impose exogenous shocks or policy changes from the baseline.

For the final version of the ABARES/NCAP agristaples model, three basic extensions were made. These extensions are required to produce the simulations results reported in the body of this report. The extensions are:

1) the model calibration to an unbalanced growth path
2) the modification of the household group demand system from a linear expenditure system to a linear approximate almost ideal demand system (LA-AIDS), and
3) the inclusion of a targeted consumer subsidy with fixed price and quota ration.

The objective of the second extension was to make the change to an unbalanced growth path as computationally easy as possible. This led to the use of a flexible functional form for a demand system. To that end, the LA-AIDS model was chosen. The objective of the third extension was to more closely approximate existing policy in India. The forms of consumer subsidy modelled in the core model are more flexible in that they take the subsidy price or prices as endogenous. The core model variants considered targeted and untargeted, and non-tradable and tradable versions. In light of existing Indian policy, the case of a targeted, non-tradable and fixed price version of the consumer subsidy policy is considered. These changes are documented together as follows.

1. Calibration to an unbalanced growth path

The approach taken to calibrate to an unbalanced growth path basically involves first calibrating to a balanced growth path (as described above) and then shocking that path to produce the "required" unbalanced path. In general, the "required" path is taken to be a given output path for each industry. This path is informed by exogenous expert sources. The trick is to find a set of production shocks that will generate this required path. This is done by exogenising the industry outputs and endogenising the production shocks in the model. This endogenous exogenous swap technique is most widely used to solve comparative static models in the ORANI tradition as pioneered by Peter Dixon of the Centre of Policy Studies, Monash University (Dixon et al.1982).

For the core model, the swap involves making use of the factor augmenting technical change term, faugtcgi, in the expression for the price of value added and for factor demands. This becomes equal to a new series, faushki, which stores any exogenous shock times an endogenous sector specific Hicks neutral primary factor technical change term, sfaugtcgi. In turn the value for sfaugtcgi is that which through the equation system exogenises industry output to a given output path, qsexo.

The additional equations added to the system are thus:

faugtcgieq(t,fg,c).. faugtcgi(t,fg,c)=sfaugtcgi(t,c)*faushki(t,fg,c)

sfaugtcgieq(t,c)..qs(t,c)=qsexo(t,c)

After the solution is obtained then the swap is reversed so that the model, including output growth, can respond to exogenous shocks. Not just any choice of industry outputs will fit the model system (feasibility) or produce sensible results. Additional flexibility was gained and model results seemed most sensible if one industry sector is left out of this calibration procedure. This is judged on the basis of an assessment of the size and time path of the technical change shocks and in simulation of a range of test shocks. For example, the transport part of the services sector was left out of the calibration procedure used in the simulation report given the wide use of this sector's product throughout the economy.

An additional exogenous technical change factor, lfaughtci, was introduced in the value added unit cost and factor demand equations (pva_dfeq and fdg_fceq) to account for additional factor augmenting technical advance. In these equations this involved substituting faugtcgi by lfaughtci*faugtcgi. This lets the effective supply of a sector specific fixed factor grow at the industry growth rate through a factor augmenting advance. It also lets the effective supply of mobile unskilled and skilled labour forces each grow at a given rate comprising exogenous supply and factor augmenting technical advance components.

2. LA-AIDS functional form

The linear expenditure system for household demand was replaced by a flexible functional form. The functional form used here for household consumer demand is the almost ideal demand system (AIDS) model formulated by Deaton and Muellbauer (1980) modified by linear approximation (LA) of the original price index using Stone's price index. This involved replacing the qdch_foceq equation as follows.

Real household group consumption of commodity defined

qdch_foceq(t,c,hh).. pdtilde(t,c,hh)*qdch(t,c,hh)=budgsh(t,c,hh)* yhdisp(t,hh)

In this equation the effective expenditure share on a commodity is defined to be the term budgsh. This is used to back out the value of consumption, qdch, given the effective consumer price, pdtilde, the budget share and household disposable income, yhdisp.

Household disposable income defined

yhdisp_dfeq(t,hh)..yhdisp(t,hh)=yh(t,hh)*(1-mps(hh))*(1-htax(t,hh))

Household disposable income is an intermediate variable introduced for ease. Household disposable income is a fixed share of household income where the share reflects the proportion to be consumed after tax (htax rate) and saving (mps rate). In the closure used for the simulations report, both htax and mps are exogenous.

Budget share max rule

budgsh_eq(t,c,hh)..budgsh(t,c,hh)=max(0,budgsh_rhs(t,c,hh))

The budget share max is an intermediate variable introduced to make sure the budget share is zero or greater, to aid finding the solution.

Budget share right hand side defined

budgsh_rhs_eq(t,c,hh).. budgsh_rhs(t,c,hh)=budgsh0(c,hh)$(dvunbal=0)+

((a_budgsh(c,hh)+

sum(c2,b_budgsh(c,c2,hh)*log(pdtilde(t,c2,hh)))+

c_budgsh(c,hh)*log(yhdisp(t,hh)/pstone(t,hh)))$(dvunbal=1))$cnserv(c) +

((1-sum(cnserv,budgsh(t,cnserv,hh)))$(dvunbal=1))$ctserv(c)

This is the actual budget share used to find the level of consumption in equation qdch_eq above. There are three equations in one in the above right hand side. First, if dvunbal=0 then this is not an unbalanced growth run and the LA-AIDS specification is to be run with a Cobb-Douglas fixed budget share specification where budgsh0 is the exogenous budget share in the base year of the model. The only reason for including this option is to start the calibration by checking first that the model can be solved for a balanced growth path.

Second, if dvunbal=1 then there is one of two situations to consider. In the first of these, a commodity belongs to the subset not transport services as indicated by cnserv(c). This is the LA-AIDS formula. The budget share is linearly sensitive to proportional changes (logs) in real commodity prices, and to a proportional change (log) in real disposable income. The underscore terms are exogenous parameters. The slope coefficients are derived using elasticity formulas given in Green and Alston (1990). The intercept term is defined using base year calibration.

The second and last condition occurs for the transport service commodity ctserv(c). For this commodity, the budget share is defined by the condition that budget shares must sum to 1 to ensure demand system consistency, including that Walras law holds in the CGE model. While the choice of commodity is somewhat arbitrary, choosing a commodity with relatively low budget share in the base year may cause computational difficulties.

Stone composite consumer price defined

pstone_eq(t,hh).. pstone(t,hh)=e=exp(sum(c,budgsh(t,c,hh)*log(pdtilde(t,c,hh))))

This is the formula for Stone's aggregate consumer price.

Note that to make the functional form change easy to follow the additional terms for the variable price consumer subsidy are omitted in the above specification for consumer demand. The procedure used in the original model version may be followed to reintroduce them. Also note that the effective consumer price is defined in what follows as part of the fixed price consumer subsidy with quota ration block.

3. Targeted consumer subsidy with fixed price and quota ration

The basic approach followed here is similar to that used to generate a tariff rate quota (see for example Bishop et al. 2001). The core essentially partial equilibrium extension involves adding 3 equations:

Effective consumer price condition

pdtilde(t,c,hh)=pd(t,c)-max(0,pd(t,c)-pcsubtg(t,c,hh)-

pcsubtx(t,c,hh))$(dvcpole(c,hh)=1)

Quota binding condition

pcsubtxeq(t,c,hh).. qdchqta(t,c,hh)+qdchmkt(t,c,hh)≥qdch(t,c,hh)

Over-quota condition

qdchmkteq(t,c,hh).. pd(t,c)-pcsubtg(t,c,hh)≥pcsubtx(t,c,hh)

The first of these equations defines the effective price, pdtilde, the consumer faces. One of two general situations applies in this equation. If the commodity and the household does not receive a ration dvcpole=0 then the effective price equals the market price, pd. Conversely, there is a quota ration in place for this commodity and household and dvcpole=1.

As modelled here, the consumer subsidy is targeted. As explained in the simulation report, low income household groups pay a fixed real price pcsubtg, up to ration volume qdchqta, on purchases of agristaples. This scheme is financed by the government and may be operated through a ration card.

Under the ration scheme, dvcpole=1, one of three cases typically arises depending on the quota location: (i) to the left (ii) equal to or (iii) to the right of the inverse consumer demand function. (See the discussion in the body of the simulation report for graphical and tabular analysis).

In equation pdtilde, the effective price is typically pcsubtg (the rationed fixed price) if pcsubtx (the endogenous consumer subsidy quota rental price) is 0 and pd otherwise. Conditions pcsubtxeq and qdchmkteq, and the related complementary slackness conditions and non negativity conditions determine which case applies.

Case i

In situation (i), actual consumption exceeds the quota, qdch>qdchqta which implies qdchmkt>0, and the consumer subsidy is not distorting as it does not affect decisions at the margin where the price faced is the market price pd. If qdchmkt>0 then the equality holds in qdchmkteq and the subsidy wedge, pd-pcsubtg, is exactly offset by the strictly positive consumer quota rental, pcsubtx, so that pdtilde=pd. When pcsubtx>0 the equality holds in pcsubtxeq and total consumption, qdch, comprises subsidized, qdchqta, and full market price, qdchmkt, components.

It costs the government (pd-pcsubtg)*qdchqta for the subsidy and the consumer cost of product is pcsubtg*qdchqta+pd*qdchmkt leaving a consumer real income transfer of pcsubtx*qdchqta. In this case, there is no difference to a direct real income transfer from the government. Consequently, gross income to the relevant household group, in equation yh_dfeq, is increased by the amount pcsubtx*qdchqta.

Case ii

The intermediate situation is situation (ii). In this case the outcome is satisfactory as the quota exactly binds, qdch=qdchqta, and there is no overquota consumption, qdchmkt=0. These model conditions are automatically satisfied if the consumer rent is zero, pcsubtx=0.

In both cases (ii) and (iii) the government pays (pd- pcsubtg)*(qdch-qdchmkt) for the subsidy. The expression for government revenue, grev_dfeq is adjusted accordingly for the three cases.

Specifically, the reduction to government revenue covering all three cases is:

sum((cstk,hh)$dvcpole(cstk,hh),csubtggov(t,cstk,hh)*qdchsub(t,cstk,hh))

where the unit subsidy wedge,csubtggov, is:

csubtggoveq(t,c,hh)..csubtggov(t,c,hh)=max(0,pd(t,c)-pcsubtg(t,c,hh))

and the subsidised quantity, qdchsub, is:

qdchsubeq(t,c,hh)..qdchsub(t,c,hh)=qdch(t,c,hh)-qdchmkt(t,c,hh)

Case iii

Situation (iii) is distorting. In this case consumption is less than the quota, qdch<qdchqta. If the quota is meant to equal or exceed the minimum agristaple use to support healthy life then this outcome is unsatisfactory and distorting. In this situation the inequality in pcsubtxeq is strict and pcsubtx=0 and qdchmkt =0 as the inequality in qdchmkteq is strict. This is the case of a specific open ended subsidy that is not fully exploited.

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