VPM2014

Vietnamese Pig Sector Model 2014

User Manual

Version 1

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Foreword

The Vietnam Pig Sector Model (VPM) was initially developed under a project funded by The Australian Centre for International Agricultural Research (ACIAR) entitled *Improving Competitiveness of Pig Producers in an Adjusting Vietnam Market*. The project was implemented by the International Livestock Research Institute (ILRI). The modelling component of this project was carried out by the International Food Policy Research Institute (IFPRI) under a subcontract to ILRI.

The initial version of the Vietnam Pig Sector Model was constructed in 2010 by Nicholas Minot[1], Karl Rich[2] and their Vietnamese collaborators – Nguyen Ngoc Que[3] and Nguyen Anh Phong. With help from a collaborative research started in late of 2010 between ILRI and Center for Agricultural Policy (CAP), the model was substantially upgraded.

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1. Introduction

The Vietnam Pig SecTor Model of the upgraded version in 2014, VPM2014, is a spatial recursive-dynamic non-linear programming model of Vietnam's pig sector, developed within the General Algebraic Modeling System (GAMS) framework. The VPM2014 model solves simultaneously for the consumer and producer equilibrium prices in related urban and rural markets of all seven regions in Vietnam by Mixed-Complementary-Problems Solver. Supply and demand are functions of price, all markets must clear (production plus imports equals consumption plus exports) and price relationships must hold. Price relationships are held through the following assumptions:

a) Producer and consumer prices relate through margins;
b) Regional prices are linked through transport and marketing costs so that the relationship between regional prices is maintained.
c) Domestic prices and world prices relate through import and export margins;

The demand side of the model is represented by a log-log model where price elasticities are calculated from an underlying regional urban-rural AIDS model for food expenditure calculated for budget shares in the base year. Over a ten year time horizon urban-rural income and population growth determine demand for a product.

The model is dynamic in that it projects changes over time in response to demand growth driven by income and population growth. Productivity growth in terms of crop productivity, yield per animal and food conversion ratios drive growth in output over time. Aside from food demand, treatment of the interaction between the Vietnamese pig sector and the rest of the economy is dealt with by using exogenous parameter assumptions that reflect economic growth paths, such as changes in urban and rural income, population and world prices.

The aim of this User Manual is to provide a guide on how to:

✓ Set up and run the VPM2014 model;
✓ Make changes to the VPM2014 model structure;
✓ Make changes to model inputs; and
✓ Control model outputs.

2. How to set up and run the VPM2014 model

GAMS modelling system

VPM2014 model uses the General Algebraic Modeling System (GAMS). GAMS software can be downloaded for free from the supplier, but to run a model of more than a specific number of variables a GAMS licence for specific solvers needs to be purchased. VPM2014 requires the basic licence which includes the necessary MCP solver[4].

GAMS can run from an operating system command line or on Windows machines using the Integrated Development Environment (IDE). Our user manual is based on use of IDE. IDE is designed to allow editing, development, debugging and running GAMS works in one program. Once installed, the IDE interface can be opened through the icon, start menu or Explorer.

Creating a GAMS project

The first step in running the VPM2014 model is to create a new GAMS project. The IDE employs a 'Project' file for two reasons:

a) The project location determines where files are saved and where GAMS looks for files when executing; and

b) The project saves file names and program options associated with the effort in a file called projectname.gpr.

To create a new project, select the 'File' menu in the upper left corner of IDE, select 'Project' and 'New Project' (Figure 1). Define a project name and locate the project in a directory where you want to use. All files associated with this project will be saved in that directory.
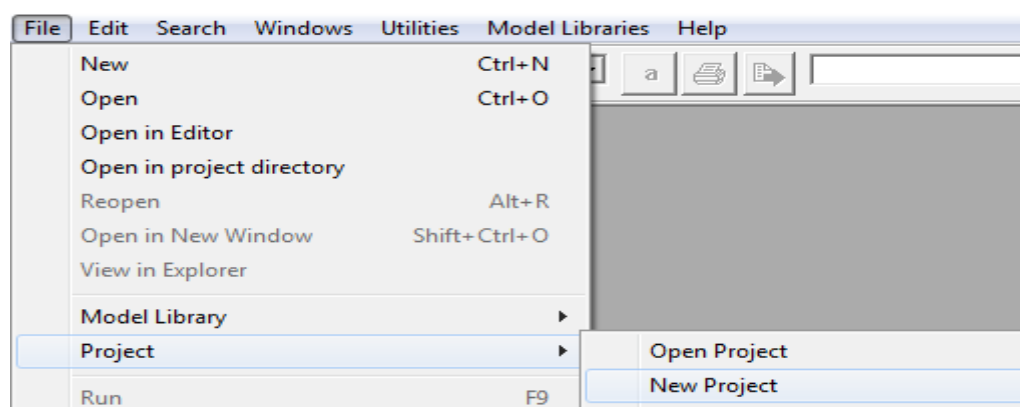
Figure 1: Saving a new project screenshot

In the "File name" area, enter in a name for the project file you wish to use (e.g. "*VPM2014*") (see Figure 2). This defines the directory where the files you wish to access are

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[4] Licence terms and conditions are available from GAMS.

located (those specified without full file path names). The extension 'gpr' stands for GAMS project.

Figure 2: Defining the project file name screenshot

Opening the VPM2014 Model files of GAMS instructions

VPM2014 contains four files of GAMS instructions:

a) VPMInput2014.gms
b) VPMCore2014.gms
c) VPMOutput2014.gms
d) VPMSim2014.gms
e) Open the first of these files from within the IDE interface by selecting the 'File' menu at the top left of the interface, selecting 'Open', locating the file "VPMSim2014.gms" and clicking on the 'Open' button (Figure 3). This file contains command lines to instructs GAMS to include "VPMInput2014.gms", "VPMCore2014.gms" and "VPMOutput2014.gms". The IDE interface allows a number of files to be open simultaneously. While all GAMS files of VPM2014 are required to be in the same file location, only the fourth (i.e. VPMSim2014.gms) needs to be open for the model to run.
f)
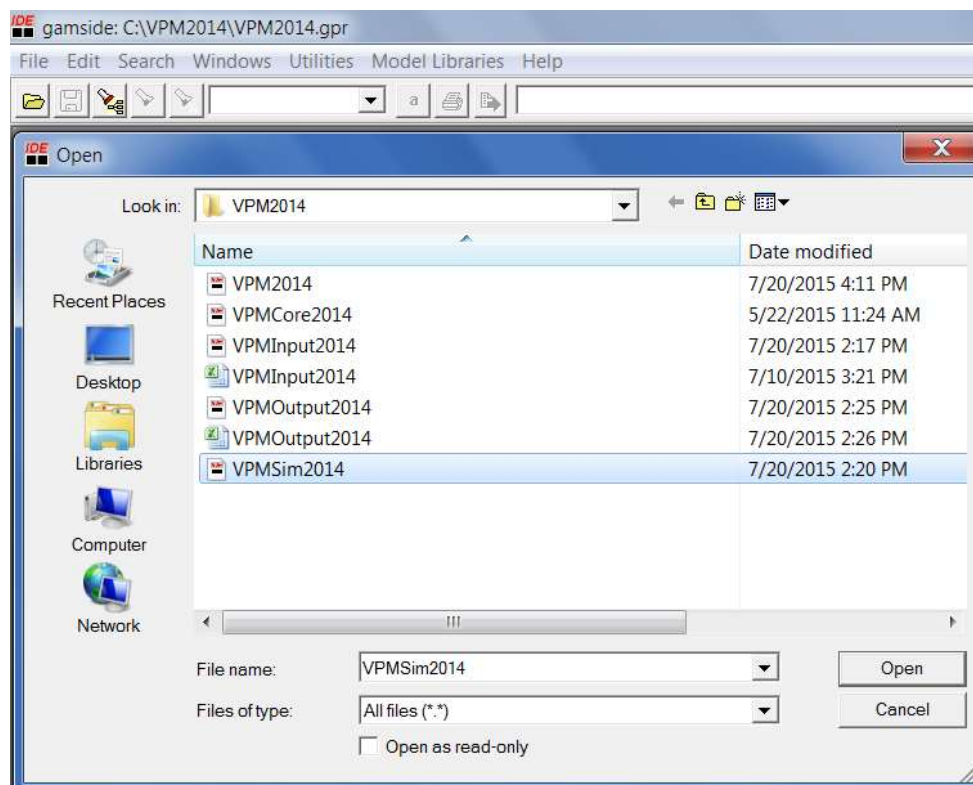
Figure 3: Opening the VPM2014 files in GAMS screenshot

Ensuring the Excel input and output files is available to GAMS

The VPM2014 Model uses input data from the excel file "VPMInput2014.xlsx" and extracts its outputs into the excel file "VPMOutput2014.xlsx". These excel spreadsheets must be available from the same file location as the three GAMS instruction files, and it must be saved. Before running the GAMS model, ensure you have this file in the correct location (Figure 3).

Running the VPM2014 Model

To run the VPM2014 Model, make sure "VPMSim2014.gms" is open and selected (If other gms files are open, ensure that "VPMSim2014.gms" is selected). Run the model by either clicking the run icon with a red arrow on the tool bar (Figure 4), selecting the 'File' menu and clicking "Run", or pressing F9.

Figure 4: Running VPM2014 model screenshot

This causes GAMS to run and the *process window* to appear, which gives a log (actually containing the LOG file) or the steps GAMS goes through in running the model. The user can narrow the *process window* and drag it to the right so that the *list file* (LST) window can be viewed (Figure 5).
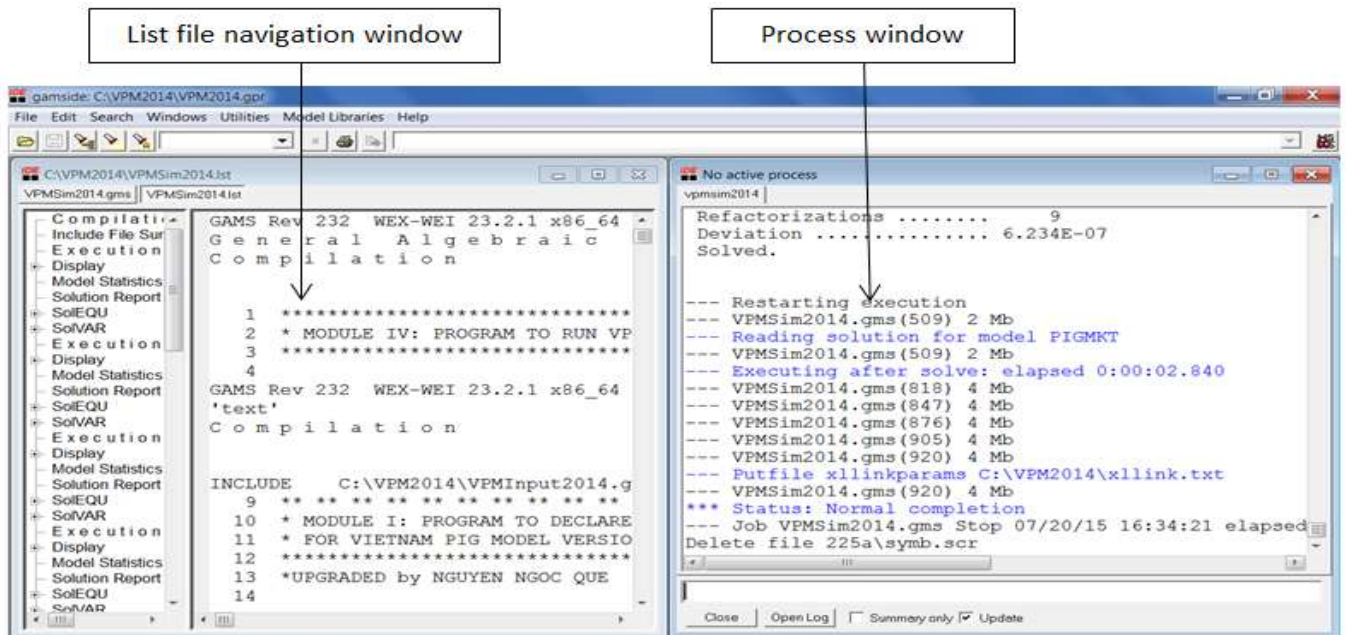
Figure 5: The process window and list file screenshot

Opening and navigating around the output
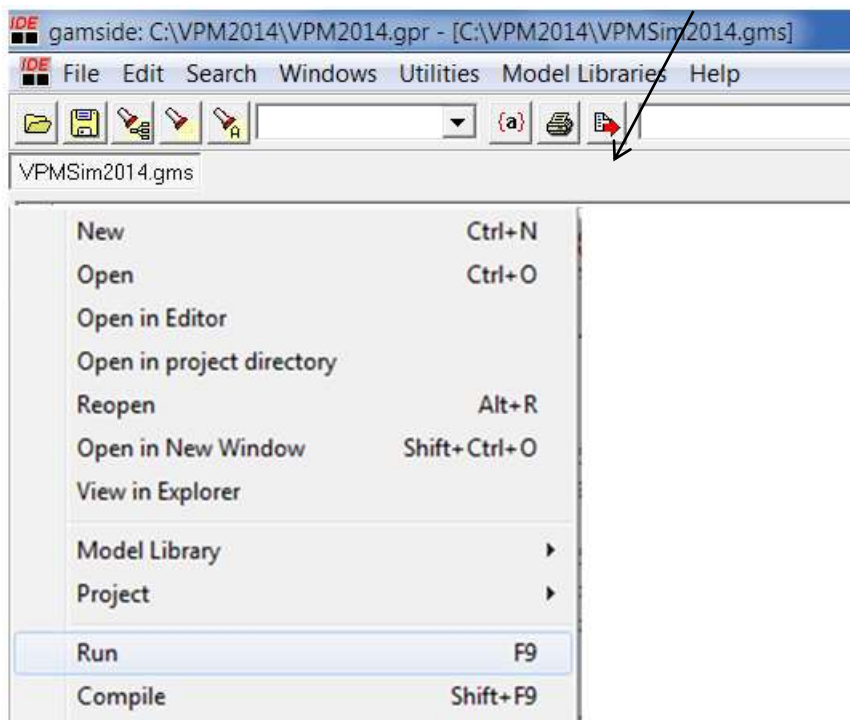
This can be done in one of two ways:

a) Using the process window

Double clicking on lines within the process window allows you to access program output in general as well as at particular locations (Figure 5). The positioning of your access is determined by the colour of the line you double click on:

- Blue line: Jumps to the line in a LST file corresponding to the blue line in the process window. Blue lines also open put and other files created by the run,
- Non-bolded black line: Jumps to the location of the last previous blue Line in the LST file, and
- Red line: Identifies errors in teh source file. When you click on a red line, the cursor jumps into the source (GMS) file at the location of the code that caused the error. Error description text appears in the process window and in the LST file that is not automatically addressed. When the shift key is held down you will go to the corresponding spot in the LST file.

b) Using the list file navigation window.

Clicking on the lines in the LST file allows access to program output both in general and at particular locations (see Figure 5). The positioning of the cursor is determined by the type of line you click on. A list of types of lines typically in the LST file is given in Table 1.

Table 1: Types of lines found in LST files

Name of Line in LST File Navigation Window	Function and Destination When Clicked
Compilation	Jumps to top of echo print in LST file
Error Messages	Jumps to list of error messages when compilation messages incurred
Equation listing	Jumps to list of equation contents as illustrated in the output section
Equation	Expandable allowing jump to beginning of list of contents for each individual equation block with contents as shown in the output section
Variable listing	Jumps to list of variable contents as illustrated in the output section
Variable	Expandable allowing jump to beginning of list of contents for each individual equation block with contents as shown in the output section
Model statistics	Jumps to model statistics part of LST file as illustrated in the output section
Solution Report	Jumps to model summary solution report
SolEQU	Expandable allowing jump to beginning of list of solution for each individual equation block with contents as shown in the output section
SolVAR	Expandable allowing jump to beginning of list of solution for each individual variable block with contents as shown in the output section
Execution	Jumps to beginning of post solve execution
Display	Expandable allowing jump to displays of specific parameters and other items

3. How to make changes to the VPM2014 Model structure

The easiest way to make changes to the VPM2014 Model structure is by changing the GAMS instructions within the gms files using the IDE interface. This requires some knowledge of the current structure of the model, and of the variable, parameter, scalar and vector names used in GAMS.

Appendix 1 presents the definitions of the model set/subset names. Column 1 provides a description, column 2 shows the GAMS set names, column 3 provides the elements included in each set.

Appendix 2 presents the definition of model input parameters. Column 1 show the GAMS input parameter names, column 2 provides a description, column 3 show the units;

Appendix 3 presents the definition of model variables, equations & other parameters. Column 1 show the GAMS variable/equation/parameter names, column 2 provides a description, column 3 show the units;

Appendix 4 presents the definition of summary model output parameters. Column 1 show the GAMS output parameter names, column 2 provides a description, column 3 show the units;

Appendix 5 presents the VPM2014 core system of equation and equalities in normal algebraical forms .

Ways to find and/or replace text strings

The dialogs for finding text within the IDE involve use of three icons on the tool bar picturing a flashlight, and the search box just to the right of the flashlight icons (Figure 6).

Figure 6: GAMS buttons used for finding text screenshot
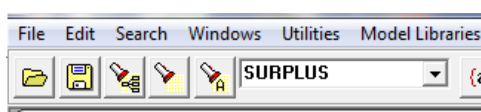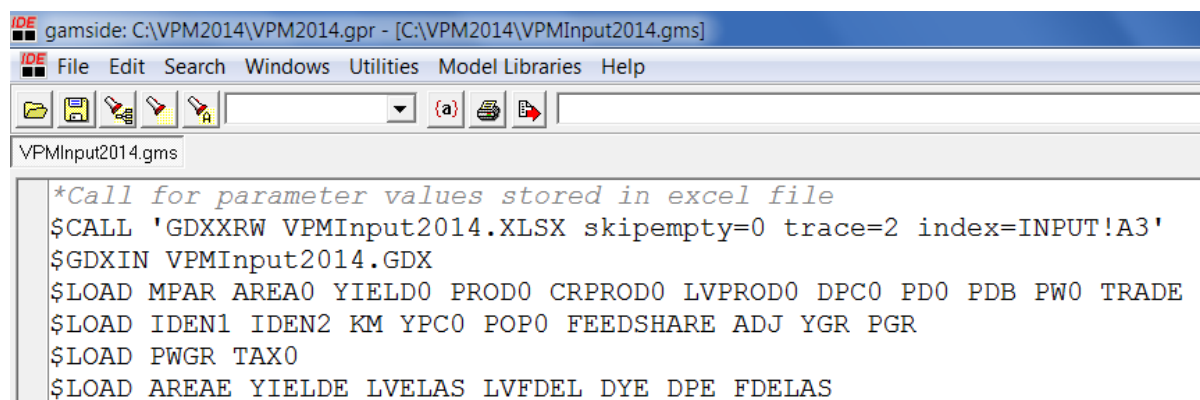
To find text, type the text string you are after in the search widow (the example in Figure 6 is "SURPLUS"). In turn, clicking on the first icon finds the first occurrence of what you want in the current file, while clicking on the second icon finds the next occurrence in the current file. Finally, clicking on the third icon finds all occurrences in a specified group of files.

4. How to make changes to model inputs

Most model inputs are housed within the excel file VPMInput2014.xls. The user can change data within this file, re-save the file and close it. If the excel file is not saved, any changes to model inputs will not be recognised within GAMS. If the user would like to change the name of the Excel file, the updated name must be changed within *"VPMInput2014.gms"* in the line reading *$CALL 'GDXXRW VPMInput2014.XLSX skipempty=0 trace=2 index=INPUT!A3'* (see Figure 7).

Figure 7: Screenshot of GAMS text which calls input data from *VPMInput2014.gms*

The excel file contains data for 29 variables. A list of these variables and their location within the spreadsheet are contained within the block A4:E32. For example, parameters called "MPAR" are to be found at INPUT!A35:F39. Users can go to this location and change the values of these parameters or exogenous variables.

The variables that users are most likely to want to change are income, population, productivity and world price growth.

A small amount of input data is housed in the GAMS file *"VPMInput2014.gms"* (see Figure 8a&b). Changes to this data must be made directly into this GAMS file.

Figure 8a: Input data within *"VPMInput2014.gms"* screenshot

Figure 8b: Input data within "*VPMInput2014.gms*" screenshot

A number of important parameters for policy shocks is located in GAMS file "*VPMSim2014.gms*" such as: Import and export quotas (QUOTA), technology growth (TGR), nominal exchange rate growth (NERGR), population growth multiplier (PGM), income growth multiplier (YGM), world price growth multiplier (PWGM), tax rate growth (TAXGR);

Figure 9: Input data within "*VPMSim2014.gms*" screenshot

VPM2014 contains a number of sets defined within "*VPMInput2014.gms*". Changes to these sets must be made directly into this file. One of these set is titled "T" and determines the number of years for which the model is run (Figure 10). When this set is defined as "/2014/", then the model will run for the baseline year only. When it is defined as "/2014*2025/", then it will run for the baseline year 2014 to year 2025 including all years in between.
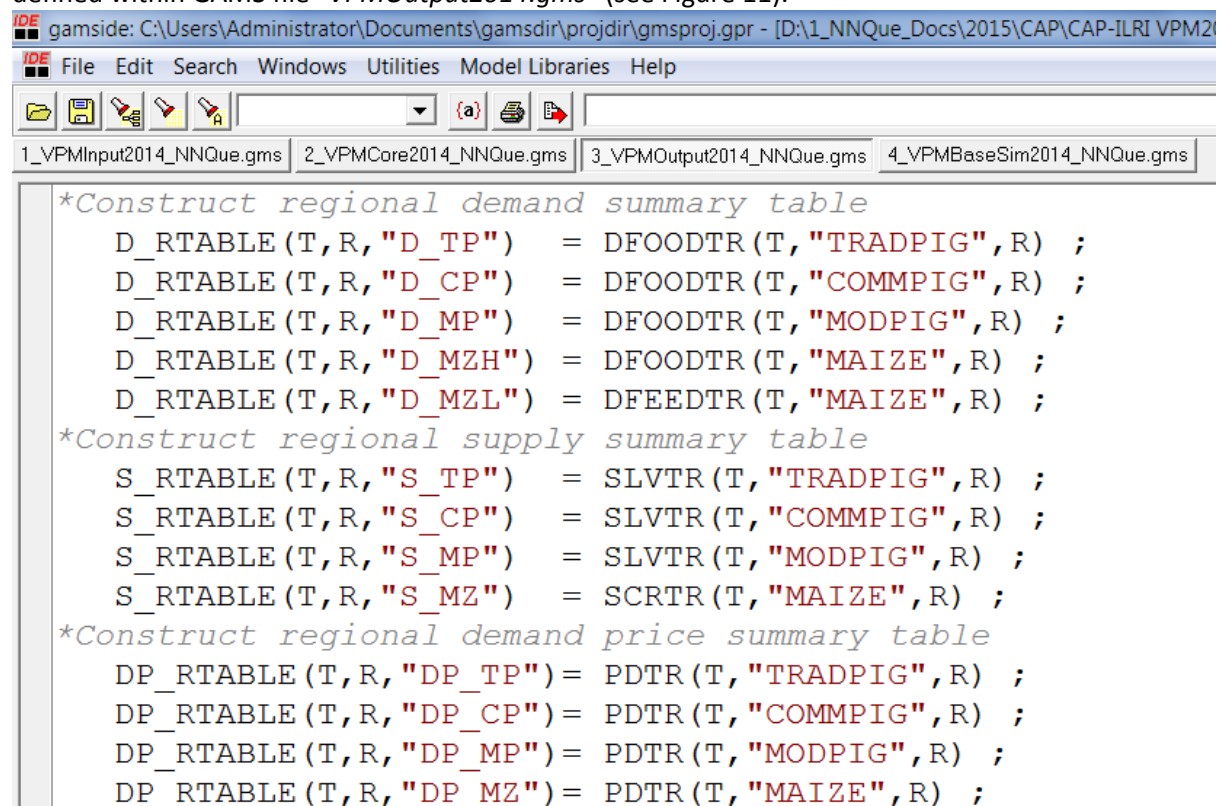
Figure 10: The definition of VPM2014 sets within "*VPMInput2014.gms*" (including number of years for which the model is run) screenshot

5. How to set up and change VPM2014 output tables

Summary output tables by regions and years for key indicators: supply, demand, trade and price are defined within GAMS file "*VPMOutput2014.gms*" (see Figure 11).

Figure 11: Screenshot of the command line for summarizing simulation output

All the calculated outputs in GAMS file "*VPMOutput2014.gms*" then are sent to excel file "*VPMOutput2014.xlsx*" using special commands ((see Figure 12):
$LIBInclude XLDUMP S_RTABLE VPMOutput2014.xlsx %sim_name%!C5:H89

Figure 12: Screenshot of the command line for sending output to excel file

The VPM2014 creates the following output summary variables and parameters:
- DFOODTR: Regional food demand at time T (1000 tons);
- DFEEDTR: Regional feed demand at time T (1000 tons);
- SCRTR: Regional crop supply at time T (1000 tons);
- SLVTR: Regional livestock supply at time T (1000 tons);
- PSTR(T,C,R): Regional producer price at time T (D per kg);
- PDTR: Regional consumer price at time T (D per kg);

- XTR: Regional exports at time T (1000 tons);
- MTR: Regional imports at time T (1000 tons);
- TQTR: Regional TQ in-out (exclude R to R) at time T (1000 tons);
- TQXTR: Regional TQ outflow at time T (1000 tons);
- TQMTR: Regional TQ inflow at time T (1000 tons);

All summary output indicators are stored in the sheet "SIM-BASE" of the excel file "VPMOutput2014.xlsx". User can use excel command to aggregate the model outputs or draw graphs or further analyze the output data.

Appendix

Appendix 1: Definition of model set names

Description	Set name	Elements in the set
Time period	T	2014*2025
All commodities	C	MAIZE, TRADPIG, COMMPIG, MODPIG
Regions incl world	RW	NMM, RRD, NCC, SCC, CH, SE, MRD, WORLD
Sub-set regions excl world	R(RW)	NMM, RRD, NCC, SCC, CH, SE, MRD
Urban & rural	U	URBAN, RURAL
Subset of livestock commodities	L(C)	TRADPIG, COMMPIG, MODPIG
Subset of crop commodities	F(C)	MAIZE

Note:

MAIZE - Crops used for human & animal; TRADPIG - Traditional pig farms; COMMPIG - Commercial pig farms; MODPIG - Modern pig farms; NMM - North Moutainous and Middle Lands; RRD - Red River Delta; NCC - North Central Coast; SCC - South Central Coast; CH - Central Highlands; SE - South East; MRD - Mekong River Delta; WORLD - Rest of world.

Appendix 2: Definition of model input parameters

Parameter name	Description	Unit
MPAR(C,*)	Market parameters: CONV, PMARGPR, CTA, XPROC, FEEDCONV	
CONV(C)	Conversion ratio from farm weight to consumer weight	
PMARGPR(C)	Processing costs	Fraction
CTA(C)	Commodity transportation cost adjustment factor	
XPROC(C)	Extra cost of processing for export	VND per Kg
FEEDCONV(C)	Amount of aggregate feed per unit of meat	
AREA0(F,R,U)	Original crop area for urban-rural consumption 2014	1000 Ha
YIELD0(F,R,U)	Original crop yield for urban-rural consumption 2014	Tons per ha
PROD0(C,R,U)	Original crop & LVSK production for urban-rural consumption 2014	1000 tons
CRPROD0(C,R,U)	Original crop prod. for urban-rural consumption 2014	1000 tons
LVPROD0(C,R,U)	Original lvstck prod. for urban-rural consumption 2014	1000 tons
DPC0(C,R,U)	Original per capita food cons. 2014	kg per year
PD0(C,R,U)	Original consumer price 2014	VND per Kg
PDB(C,R,U)	Base scenario consumer price	VND per Kg
PW0(C,*)	Original world prices 2014	US$ per ton
TRADE(C,*)	Import and export volumes 2014	1000 tons
IDEN1(C,F)	Identity matrix for proper dimension of feed demand in inflows	
IDEN2(C,L)	Identity matrix for proper dimension of livestock Supply in outflows	
KM(RW,RRW,*)	Distance	Km
YPC0(R,U)	Urban & rural per capita income in 2014	Mill. VND per year

		1000 inhabitants
POP0(R,U)	Urban & rural population in 2014	1000 inhabitants
FEEDSHARE(L,F)	Share of each feed in total composite feed demanded by animal	Fraction
ADJ(C,*)	Adjustment factor to match VHLSS consumption with national data	
YGR(R,U)	Annual income growth 2015-25	Fraction
PGR(R,U)	Annual pop growth 2015-25	Fraction
AREAE(F,R)	Elasticity of crop area with respect to output price	
YIELDE(F,R)	Elasticity of crop yield with respect to output price	
LVELAS(L,LL,R)	Elasticity of livestock supply with respect to output prices	
LVFDEL(L,F)	Elasticity of livestock supply with respect to feed prices	
DYE(C,R,U)	Food demand elasticity with respect to consumer income	
DPE(C,CC,R,U)	Food demand elasticities with respect to food prices	
FDELAS(F,F)	Elasticity feed Demand with respect to feed own prices	
PWGR(T,C)	Annual growth of world prices	
NER0	Nominal exchange rate in 2014	1000 VND per US$
DFOOD0(C,R,U)	Original food demand	1000 tons
DFEED0(C,R,U)	Original feed demand	1000 tons
D0(C,R,U)	Original food-feed demand	1000 tons
S0(C,R,U)	Original product supply	1000 tons
NATD0(C)	National food-feed demand	1000 tons
NATS0(C)	National product supply	1000 tons
TP(RW,RRW)	Cost of transportation	VND per Kg
MARGPR(C,R,U)	Processing costs	VND per Kg
MARGD(C,R,RR,U)	Marketing margin for internal trade	VND per Kg
MARGM(C,R,U)	Marketing margin for imports	VND per Kg
MARGX(C,R,U)	Marketing margin for exports	VND per Kg
MARGW(C)	Margin between world FOB and CIF prices	US$ per ton
PS0(C,R,U)	Original producer price	VND per Kg
PSB(C,R,U)	Producer price in base scenario	VND per Kg
FEEDNAT(C)	Original national feed demand	1000 tons

Appendix 3: Definition of model variables, equations & other parameters

Variable name	Description	Unit
Positive variables		
PS(C,R,U)	Producer price	VND per kg
PD(C,R,U)	Consumer price	VND per kg
TQ(C,R,RR,U)	Transport of goods	1000 tons
X(C,R,U)	Exports	1000 tons

M(C,R,U)	Imports	1000 tons
IXT(C)	Implicit export tax	VND per kg
IMT(C)	Implicit import tax	VND per kg
Variables		
DFOOD(C,R,U)	Demand for food	1000 tons
DFEED(F,R,U)	Demand for feed	1000 tons
AR(F,R,U)	Planted area of feed	1000 ha
YLD(F,R,U)	Yields of feed crops	Tons per ha
SCR(F,R,U)	Supply of feed crops	1000 tons CW
SLV(L,R,U)	Supply of livestock	1000 tons CW
PW(C)	World FOB price	US$ per ton
Equations		
AREA	Crop area equation	
YIELD	Crop yield equation	
CSUPPLY	Crop supply equation	
LSUPPLY	Livestock supply equation	
FOODDEM	Food demand equation	
FEEDDEM	Feed demand equation	
INFLOW	Shipments into region	
OUTFLOW	Shipments out of region	
DOM_TRADE	Domestic trade	
IMPORTS	Imports	
EXPORTS	Exports	
MQUOTA	Import quota limits	
XQUOTA	Export quota limits	
Dynamic parameters		
SCRT(F,R,U,T)	Supply of crops at time T	1000 tons CW
SLVT(L,R,U,T)	Supply of livestock at time T	1000 tons CW
DFOODT(C,R,U,T)	Demand for food at time T	1000 tons CW
DFEEDT(F,R,U,T)	Demand for feed at time T	1000 tons CW
TQT(C,R,RR,U,T)	Transport from one region to another at time T	1000 tons CW
XT(C,R,U,T)	Exports at time T	1000 tons CW
MT(C,R,U,T)	Imports at time T	1000 tons CW
PST(C,R,U,T)	Producer price at time T	VND per kg
PDT(C,R,U,T)	Consumer price at time T	VND per kg
PWT(C,T)	World (FOB) price at time T	US$ per ton
YPCT(R,U,T)	Income per capita at time T	Mill. VND per year
POPT(R,U,T)	Population at time T	1000 inhabitants
NERT(T)	NER at time T	1000 VND per US$
Policy parameters		
TAX(C,*)	Import and export taxes	Fraction
QUOTA(C,*)	Import and export quotas	1000 tons

TGR(C)	Technological growth rate for each commodity	Fraction
SGR(C)	Supply growth scaling factor	
NERGR	Growth rate of NER	Fraction
DYEG(C,U)	Annual income elasticity grow	
DYEC(C,U)	Income elasticity multiplier	
PGM	Population growth multiplier	
YGM	Per capita income growth multiplier	
PWGM(C)	World price growth multiplier	

Appendix 4: Definition of summary model output parameters

Parameter name	Description	Unit
Set of regional summary statistics for each period		
DFOODTR(T,C,R)	Regional food demand at time T	1000 tons
DFEEDTR(T,C,R)	Regional feed demand at time T	1000 tons
SCRTR(T,F,R)	Regional crop supply at time T	1000 tons
SLVTR(T,L,R)	Regional livestock supply at time T	1000 tons
PSTR(T,C,R)	Regional producer price at time T	VND per kg
PDTR(T,C,R)	Regional consumer price at time T	VND per kg
XTR(T,C,R)	Regional exports at time T	1000 tons
MTR(T,C,R)	Regional imports at time T	1000 tons
TQTR(T,C,R,RR)	Regional TQ in-out (exclude R to R) at time T	1000 tons
TQXTR(T,C,R,RR)	Regional TQ outflow at time T	1000 tons
TQMTR(T,C,RR,R)	Regional TQ inflow at time T	1000 tons
Set of summary regional output tables		
D_RTABLE(T,R,*)	Regional summary demand table	
S_RTABLE(T,R,*)	Regional summary supply table	
DP_RTABLE(T,R,*)	Regional summary demand price table	
SP_RTABLE(T,R,*)	Regional summary supply price table	
XM_RTABLE(T,R,*)	Regional summary trade table	
TQX_RTABLE(R,RR,T,*)	Regional summary TQ-out table	
TQM_RTABLE(RR,R,T,*)	Regional summary TQ-in table	
NETOUTFL_RTABLE(T,R,*)	Regional summary net outflow table	

Appendix 5: Definition of model core structure

VPM2014 has 13 block of equations (and inequalities) with 778 single equations (and inequalities), and 14 blocks of variable with 782 single variables. The system of equations (and inequalities) is solved using Mixed Complememtary Problems (MCP) programing in GAMS environment repeatedly for each of 10 selected time periods from 2015 to 2025.

The details of VPM2014 structure in normal mathematical form is as follows:

1. Group of variables:

$P_{c,r,u}^S$: Producer price (VND per kg);

$P_{c,r,u}^D$: Consumer price (VND per kg);

$TQ_{c,r',r,u}$: Transport of goods (1000 tons);

$X_{c,r,u}$: Exports (1000 tons);

$X_{c,r,u}$: Imports (1000 tons);

IXT_c: Implicit export tax (VND per kg);

IMT_c: Implicit import tax (VND per kg);

$D_{c,r,u}$: Demand for food (1000 tons);

$D_{f,r,u}^F$: Demand for feed (1000 tons);

$AR_{f,r,u}$: Planted area of crops (1000 ha);

$YLD_{f,r,u}$: Yields of crops (tons per ha);

$S_{f,r,u}^F$: Supply of crops (1000 tons of consumer weight);

$S_{l,r,u}^L$: Supply of livestock (1000 tons of consumer weight);

P_c^W: World F.O.B. price (US$ per ton).

2. System of equations & inequalities:

2.1. Crop area equation in normal mathematical form:

$$\log(AR_{f,r,u}) = \alpha_{f,r,u}^A + \Sigma_{f'}[\beta_{f,f',r,u}^A * \log(P_{f',r,u}^{SF})]$$

Where:

AR: Feed crop area;

α^A: Intercept of crop area function;

β^A: Elasticity of feed crop area with respect to its own & cross-prices;

P^{SF}: Feed crop producer price;

f and f': Feed crop index and its alias;

r: Region index;

u: Urban-rural index.

2.2. Crop yield equation in normal mathematical form:

$$\log(YLD_{f,r,u}) = \alpha_{f,r,u}^Y + \beta_{f,r,u}^Y * \log(P_{f,r,u}^{SF})$$

Where:

YLD: Crop yield;

α^Y: Intercept of feed crop yield function;

β^Y: Elasticity of feed crop yield with respect to its own price.

2.3. Crop supply equation in normal mathematical form:

$$S_{f,r,u}^F = (AR_{f,r,u} * YLD_{f,r,u}) * CNV_f$$

Where:

S^F: Feed crop supply;

CNV_f: Conversion ratio from producer weight to consumer weight for feed crops.

2.4. Livestock supply equation in normal mathematical form:

$$\log(S_{l,r,u}^L) = \alpha_{l,r,u}^L + \Sigma_{l'}[\beta_{l,l',r,u}^L * \log(P_{l',r,u}^{SL})] + \Sigma_f[\gamma_{l,f,r,u}^L * \log(P_{f,r,u}^{SF})]$$

Where:

S^L: Livestock supply;

α^L: Intercept of livestock supply;

β^L: Elasticity of livestock supply with respect to own and cross-price of livestock products;

γ^L: Elasticity of livestock supply with respect to feed crop producer price;

P^{SL}: Livestock producer price;

l and l′: Livestock index and its alias.

2.5. Food demand equation in normal mathematical form:

$$\log(D_{c,r,u}) = \alpha^D_{c,r,u} + \sum_{c'}\left[\beta^D_{c,c',r,u} * \log(P^D_{c',r,u})\right] + \gamma^D_{c,r,u} * \log(Y_{r,u}) + \log POP_{r,u} * 1000$$

Where:

D: Food demand;

α^D: Intercept of food demand;

β^D: Elasticity of food demand with respect to own and cross-price of food;

γ^D: Elasticity of food demand with respect to consumer income;

P^D: Food demand price;

Y: Consumer income;

c and c′: All commodity (all food) index and its alias;

POP: Population.

2.6. Feed demand equation in normal mathematical form:

$$\log(D^F_{f,r,u}) = \alpha^F_{f,r,u} + \sum_{f'}\left[\beta^F_{f,f',r,u} * \log(P^{DF}_{f',r,u})\right] + \sum_{l}\left[\gamma^F_{f,l,r,u} * \log(P^{SL}_{l,r,u})\right] + \log\left(\sum_{l} S^L_{l,r,u}\right)$$

Where:

D^F: Feed demand;

α^F: Intercept of feed demand;

β^F: Elasticity of feed demand with respect to own and cross-price of feed;

γ^F: Elasticity of feed demand with respect to livestock producer price;

P^{DF}: Feed demand price.

2.7. Commodity inflow inequality in normal mathematical form:

$$\sum_{r'} TQ_{c,r',r,u} + M_{c,r,u} \geq D_{c,r,u} + \sum_{f}\left[ID^1_{c,f} * D^F_{f,r,u}\right]$$

Where:

TQ: Transport-in commodity quantity;

M: Commodity import;

ID^1: Identity matrix for proper dimension of feed demand/supply in inflows.

2.8. Commodity outflow inequality in normal mathematical form:

$$\sum_{l}\left[ID^2_{c,l} * S^L_{l,r,u}\right] + \sum_{f}\left[ID^1_{c,f} * S^F_{f,r,u}\right] \geq \sum_{r'} TQ_{c,r,r',u} + X_{c,r,u}$$

Where:

TQ: Transport-out commodity quantity;

X: Commodity export;

ID^2: Identity matrix for proper dimension of livestock supply in inflows.

2.9. Domestic trade inequality in normal mathematical form:

$$P^S_{c,r,u}/CNV_c + MARG^D_{c,r,r',u} \geq P^D_{c,r',u}$$

Where:

P^S: Commodity producer price;

P^D: Commodity consumer price;

CNV_c Commodity conversion ratio from producer to consumer weight;

$MARG^D$: Marketing price margin for internal trade.

2.10. Import inequality in normal mathematical form:

$$(P^W_c + MARG^W_c) * NER * (1 + TAX^M_c) + IMT_c + MARG^M_{c,r,u} \geq P^D_{c,r,u}$$

Where:

P^W: World commodity (FOB) price;

$MARG^W$: World commodity price margin (CIF-FOB);

TAX^M: Import tax in fraction;

IMT: Implicit import tax;

$MARG^M$: Commodity import price margin.

2.11. Export inequality in normal mathematical form:

$$P^S_{c,r,u}/CNV_c + MARG^X_{c,r,u} + IXT_c \geq P^W_c * NER * (1 - TAX^X_c)$$

Where:

TAX^X: Export tax in fraction;

IXT: Implicit export tax;

$MARG^X$: Commodity export price margin.

2.12. Import quota limit inequality in normal mathematical form:

$$QT^M_c \geq \sum_r \sum_u M_{c,r,u}$$

Where:

QT^M: Import quota limits.

2.13. Export quota limit inequality in normal mathematical form:

$$QT^X_c \geq \sum_r \sum_u X_{c,r,u}$$

Where:

QT^X: Export quota limits.