A CGE MODEL FOR INDIA WITH AN APPLICATION ON THE EFFECTS OF ELIMINATING AGRICULTURAL SUBSIDIES

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Contents

Summary

(1) In 2015 the National Council for Applied Economic Research (NCAER) in New Delhi and Victoria University in Melbourne signed a memorandum of understanding (MOU) to promote co-operation in applied research on the Indian economy focused around computable general equilibrium (CGE) modelling. This paper is the first product of co-operation under the MOU.

(2) Because of its flexibility and realism, CGE has gradually become the dominant form of economy-wide modelling (modelling that provides industry disaggregation in a quantitative description of the whole economy). Over the last 50 years, CGE models have been used in the analysis of an enormous variety of policy-relevant questions.

(3) This paper describes the construction and initial application of the first version of the NCAER-VU CGE model.

(4) In building the model, we have transformed input-output data published by India Statistics into a form suitable for CGE modelling. We have also expended considerable effort in processing data on agricultural land use with the aim of facilitating applications concerned with agricultural policy.

(5) In developing NCAER-VU we are emphasizing applications and back-of-the-envelope (BOTE) explanations and justifications of results.

(6) Although NCAER-VU is at an early stage of development, it has already generated potentially important insights on the effects of agricultural subsidies. We find that:

- agricultural subsidies are worth about 2.5 per cent of GDP with about 1/3rd being subsidies on inputs of Fertilizer and Electricity to agricultural industries and about 2/3^{rds} being subsidies on production and sales of agricultural products.
- agricultural subsidies inflict a GDP dead-weight loss of about 0.20%, most of which is associated with the subsidies on Fertilizer and Electricity. The percentage loss in economic welfare measured by foregone consumption is about 0.24%.
- agricultural output is about 2.3% greater with subsidies than without.
- agricultural subsidies increase output and exports of Cotton textiles, Edible oil, Woollen textiles, Khadi and Apparel, but reduce output and exports of Communication equipment, Non-ferrous metals and Computer services.
- about 20% of Fertilizer output and 7% of Electricity output depend on agricultural subsidies.
- Fertilizer and Electricity subsidies do not contribute to the objective of supporting farm income. By inducing substitution against factors that contribute to farm income (agricultural land, and labour & capital used on farms), Fertilizer and Electricity subsidies reduce real farm income by about 2%. By contrast, production and sales subsidies on agricultural products boost real farm income by about 5%.
- all of the current agricultural subsidies contribute positively to food security. The subsidies reduce food prices relative to the CPI by about 7% and increase food consumption by about 0.7%.
- If government provision of Fertilizer and Electricity subsidies to the agricultural sector were phased out and replaced with additional provision of agricultural production and sales subsidies, then real farm income would be increased by about 4% with no deterioration in the public sector budget, almost no effect on food security, and small increases in GDP and overall welfare.

1. Introduction

In 2015 Dr Shekhar Shah, Director-General, National Council for Applied Economic Research (NCAER) in New Delhi and Professor Warren Payne, Pro Vice-Chancellor, Research and Research Training, Victoria University in Melbourne signed a memorandum of understanding (MOU) on behalf of their institutions to promote co-operation in applied research on the Indian economy focused around computable general equilibrium (CGE) modelling. NCAER has a 50-year history of applied, policy-relevant research on the Indian economy. Victoria University's Centre of Policy Studies (CoPS) has a 40-year history in CGE modelling in Australia, the U.S. and many other countries. This paper is the first product of the MOU between NCAER and Victoria University.

1.1. What is CGE modelling?[1]

CGE belongs to the economy-wide class of models, that is, those that provide industry disaggregation in a quantitative description of the whole economy. Economy-wide models emphasize the links between different parts of the economy. The first economy-wide model was Leontief's (1936, 1941) input-output model, which quantified links between industries as suppliers and customers for each other's products. In Leontief's world, an increase in household demand for cars stimulates the motor vehicle industry, which in turn stimulates the steel industry, which in turn stimulates the iron ore and coal industries, etc. Following Leontief, the next stage of economy-wide modelling was the programming models of Sandee (1960), Manne (1963), Evans (1972) and others.

Input-output and programming models lacked clear descriptions of the behaviour of individual agents. In input-output modelling, the *economy* organized production of each commodity (the vector X) to satisfy a vector of final demands (the vector Y) with given technology specified by the input-output coefficient matrix (A). In programming models, the *economy* organized production to maximize a welfare function subject to Leontief's technology specification and subject to constraints on the availability of primary factors.

CGE modelling started with Johansen (1960). By contrast with the earlier economy-wide models, Johansen's CGE model identified behaviour by *individual agents*. Households in CGE models maximize utility subject to their budget constraint. Industries choose inputs to minimize costs subject to production-function constraints and the need to satisfy demands for their outputs. Capitalists allocate capital between industries to maximize their returns. The overall outcome for the economy is determined by the actions of individual agents co-ordinated through price adjustments that equalize demand and supply in product and factor markets.

Relative to input-output and linear programming models, CGE models are an effective framework for understanding how different parts of the economy are linked. CGE models go much further than supply/customer links. CGE models emphasize links provided by competition for scarce resources: labor in different skill categories; capital; and land. As originally recognized by Johansen, an industry may be harmed by the expansion of other industries through shortages of labor and capital. Johansen's CGE model balanced the benefits of Leontief's supply/customer links against the inhibiting effects of increases in the costs of labor and capital. Modern CGE models emphasize links occurring through the exchange rate which connects import-competing and export-oriented industries. This is important in analyzing tariff policy. With cuts in protection, import-competing industries contract, lowering the exchange rate and allowing expansion of export-oriented industries.

[1] This subsection draws on material that will be published in Dixon *et al.* (2016).

Another link encapsulated by modern CGE models is through the public-sector budget and competition for scarce public funds.

Because of their flexibility and realism, CGE models have gradually become the dominant form of economy-wide model. Over the last 50 years, they have been used in the analysis of an enormous variety of questions. These include:

the effects on

- macro variables, including measures of nation-wide or even global economic welfare;
- industry variables;
- regional variables;
- labor market variables;
- distributional variables; and
- environmental variables

of

- taxes, tariffs and public expenditures;
- environmental policies;
- technology developments;
- changes in international commodity prices and interest rates;
- labor market policies and union behavior;
- exploitation of mineral deposits (the Dutch disease); and
- terrorism and other disruptive events.

Although CGE modelling has proved valuable in policy analysis, it has met considerable resistance from parts of the economics profession. There is a feeling that CGE models are black boxes. This is understandable because the theory, data and computational requirements for CGE models are daunting relative to those for input-output models. In an effort to increase accessibility of CGE modelling, its practitioners have been active in providing textbooks[2] and training not only for economists but also for policy advisors. CoPS and Purdue University's Global Trade Analysis Project (GTAP) are prominent training providers with courses in many parts of the world including Washington DC. CGE modellers have also worked hard to increase the transparency of their results through a variety of means including back-of-the-envelope (BOTE) justifications that can be readily understood by people without CGE backgrounds (see, for example, Dixon and Rimmer, 2013).

1.2. The rest of this paper: the development and first application of the NCAER-VU model

The rest of this paper has two main largely self-contained sections (sections 2 and 3). Concluding remarks are in section 4.

Section 2 describes the development of the first version of the NCAER-VU model of India. The starting point for this model is GEMPACK code written by Horridge (2000) for the ORANI-G model. ORANI-G is a generic version of the ORANI model which was originally implemented with Australian data (see Dixon *et al.* 1977 and 1982).[3] Horridge's

[2] See, for example, Burfisher (2011).

[3] The original ORANI model made several innovations in CGE modelling including: imperfect substitution between imported and domestic commodities; flexible closures; technology and tax variables associated with every commodity and factor flow; distinction between purchasers and basic prices; explicit specification of margin activities; and large dimensions (100+ industries). Overviews of ORANI applications and their role in policy discussions can be found in Powell and Snape (1993), Powell and Lawson (1990) and Vincent (1990).

ORANI-G code has been the starting point for models of many countries including: China, Thailand, South Africa, Korea, Pakistan, Brazil, the Philippines, Japan, Ireland, Vietnam, Indonesia, Venezuela, Taiwan and Denmark.

With the ORANI theory well-documented elsewhere, our description of the NCAER-VU model focuses on data, although we do sketch salient points concerning theory and computation. On the data, we are mainly concerned with the translation of input-output data published by India Statistics into a form suitable for use in a CGE model such as ORANI. The other focus in our description of NCAER-VU is special-purpose modifications to facilitate applications to agricultural policy issues. Documentation of both data manipulations and special-purpose modifications is essential in a project of the type that we envisage under the NCAER-VU memorandum of understanding. Under the MOU, there will be a series of modelling developments, each building on earlier work, possibly with different personnel. Some anticipated future developments are outlined in concluding remarks (section 4).

In any long-term modelling project it is important to perform applications as early as possible. There is a temptation to wait for the fully developed model. This should be resisted for several reasons. First, the fully developed model is never going to happen: we can always think of another improvement. Second, applications guide improvements. They help us to identify where we should put our effort in improving theory and data from the point of view of using the model to elucidate policy issues of contemporary importance. Third, frequent applications with fascinating and potentially policy-relevant results are required for maintaining research momentum. Without applications, a modelling project will soon falter. Applications are necessary to maintain interest by researchers, funders and policy analysts.

In this spirit, section 3 presents an application of the first version of the NCAER-VU model to the analysis of the effects on the Indian economy of removing agricultural subsidies. We explain and justify the results with BOTE arguments relying on: demand and supply diagrams; consumer and producer surplus calculations; and regression testing of hypotheses concerning the workings of the model. These approaches provide assurance to the modelling team that data have been assembled correctly and that solutions are valid. Checks of this nature are especially important for a model at an early stage of development.

Of broader interest is the idea that BOTE calculations and tests allow us to understand what really drives a given set of results. In qualitative terms, the pure theory of CGE modelling suggests that every result depends on every assumption and data item through a system of simultaneous equations. However, in quantitative terms, for any given set of results there is always a small number of key determining assumptions and data items. By identifying these through BOTE analyses, we provide a basis for assessing results and answering questions such as: are the key assumptions and data items sufficiently plausible for us to have faith in the results; and how would the results be affected if we changed a particular assumption or data item. BOTE analyses are also vital for communicating CGE results to people outside the CGE field. As already mentioned, BOTE analyses are important for dispelling the black-box perception of CGE modelling.

2. Introduction to the basic design of a CGE model and progress on the NCAER-VU model of India

Most CGE models start with an input-output database which gives a quantitative picture of the economy for a given year (the base year or year 0). To a large extent, a CGE model can be thought of as a system of equations that describe the movements in the components of the input-output database away from their year 0 values. The input-output table gives an initial solution. The emphasis is on movements away from the initial solution.

In comparative-static analysis these movements take the economy from the initial picture of year 0 to an alternative picture of year 0. In dynamic analysis, the movements take the economy from year 0 to a picture of year 1, say. Then further computations can show how the economy moves from year 1 to year 2, etcetera.

The equations describing the movements in the components of the input-output database are derived from neoclassical optimizing assumptions (utility maximizing, profit maximizing, cost minimizing) tied together by demand and supply equations and zero-pure-profit equations. Because of our emphasis on movements from one picture of an economy to another, it is natural for us to present the equations in percentage change form, that is, as connecting percentage changes in variables. The percentage change form can also be interpreted as a linear approximation to the true equations (those consistent with the model's theory and data). The linear approximation is the basis for an effective and simple computational method.[4]

In subsection 2.1 we describe an ideal input-output database for a CGE model and the relationship between the input-output data and the national accounts. Understanding this relationship is important in checking and interpreting CGE results and in understanding how CGE modelling is related to macroeconomics.

In subsection 2.2 we set out some illustrative CGE equations and show how their implementation uses the input-output data. Also in subsection 2.2, we discuss the percentage-change solution technique for CGE models, originally implemented in linear approximation form by Johansen (1960) but now implemented in a multi-step form that eliminates linearization errors.

Input-output data published by national statistical agencies are never in the ideal form for CGE modelling. In subsections 2.3 and 2.4 we discuss the published input-output data for India and the modifications that we have made. These fall into two categories. First, there are modifications that are necessary to improve the suitability of the data for use in any CGE model (subsection 2.3). Second, there are modifications designed specifically for a CGE model focused on agricultural issues (subsection 2.4).

2.1. The starting point: the input-output database

For understanding how a CGE model is constructed and encapsulates links between different parts of the economy, it is useful to study Figure 1. This is a slightly simplified representation of the input-output database used in well-established single-country CGE models such as the USAGE model of the United States (Dixon *et al.*, 2013).

Figure 1 has two parts, an absorption matrix and a vector of tariff collections on imports. The first row of the absorption matrix, V1BAS, … , V6BAS, shows flows in the database year (year 0) of commodities to producers, investors, households, exports, public consumption and inventory accumulation. Each of these matrices has C×S rows, one for each of C commodities from S sources. Here we will assume that S is 2, domestic and imported.[5] This is currently the situation in NCAER-VU. C can be large, 150 in the current version of NCAER-VU.

[4] See Horridge *et al.* (2013) for a comparison of GEMPACK software, which relies on the percentage change representations of models, and GAMS software in which models are presented in levels form. The comparison is highly favourable to GEMPACK.

[5] Some CGE models, even single country models, identify many sources of supply for imports, making S large.

Figure 1. Input-Output Database for a typical single-country CGE model

		Absorption Matrix					
		1	2	3	4	5	6
		Prod-ucers	Invest-ors	House-holds	Exports	Govern-ment	Invent-ories
	Size	← I →	← I →	← 1 →	← 1 →	← 1 →	← 1 →
Basic Flows	↑ $C\times S$ ↓	V1BAS	V2BAS	V3BAS	V4BAS	V5BAS	V6BAS
Margins	↑ $C\times S\times N$ ↓	V1MAR	V2MAR	V3MAR	V4MAR	V5MAR	V6MAR
Sales Taxes	↑ $C\times S$ ↓	V1TAX	V2TAX	V3TAX	V4TAX	V5TAX	V6TAX
Labor	↑ M ↓	LABOR					
Capital	↑ 1 ↓	CAPITAL					
Land	↑ T ↓	LAND					
Production taxes	↑ 1 ↓	V0TAX					
Output	↑ 1 ↓	VOUTPUT					

C = Number of commodities
I = Number of industries
S = Number of sources of commodities
M = Number of occupations
N = Number of commodities used as margins
T = Number of types of land

	Import Duty
Size	← 1 →
↑ C ↓	TARIFF

V1BAS and V2BAS each have *I* columns where *I* is the number of industries. The typical component of V1BAS is the value of good c from source s [good (c,s)] used by industry i as an input to current production, and the typical component of V2BAS is the value of (c,s) used to create capital for industry i. As shown in Figure 1, V3BAS, V4BAS, V5BAS and V6BAS each have one column. Thus, Figure 1 refers to a model that recognizes one household, one category of public demand, one destination for exports and one category of inventory demand. These dimensions can be extended in work concerned with income distribution, multiple levels of government, and trade agreements in which the essence is special access for exports to particular markets.

All of the flows in V1BAS, … , V6BAS are valued at basic prices. The basic price of a domestically produced good is the price received by the producer (that is the price at the factory door or the farm gate, or equivalently, the price paid by users excluding sales taxes, transport costs and other margin costs). The basic price of an imported good is the landed-duty-paid price, i.e., the price at the port of entry just after the commodity has cleared customs.

Costs separating producers or ports of entry from users appear in the input-output data in the margin matrices and in the row of sales-tax matrices. The margin matrices, V1MAR, … , V6MAR, show the values of N margin commodities used in facilitating the flows identified in V1BAS, … , V6BAS. The margin commodities in USAGE are the domestic varieties of: wholesale trade; retail trade; road transport; rail transport; water transport internal; air transport internal; pipelines; water transport international; and air transport international. Each of the matrices V1MAR, … , V6MAR has C×S×N rows corresponding to the use of N margin commodities in facilitating flows of C commodities from S sources. The sales tax matrices V1TAX, … , V6TAX show collections of sales taxes (positive) or payments of subsidies (negative) associated with each of the flows in the BAS matrices.

Payments by industries for M occupational groups are recorded in Figure 1 in the matrix LABOR. In models and applications focusing on labour-market issues, such as training needs and immigration, M can be large. For example, some versions of the USAGE model distinguish 350 occupations.

In most CGE models, payments by industries for the use of capital are recorded in the input-output data as a vector: CAPITAL in Figure 1.

Payments by industries for using land of T types are recorded in the matrix LAND. In different versions of the USAGE model the dimension of T varies from 1 to 72. Usually substantial entries for LAND occur only in agricultural industries.

Productions taxes and subsidies are recorded in the row V0TAX.

As an accounting truism, the value of inputs to an industry equals the value of output, VOUTPUT in Figure 1. This can be ensured by calculating the returns to capital as a residual after deducting the cost of other inputs from the value of output. Then under the assumption that each commodity is produced by just one industry and each industry produces just one commodity, the absorption matrix satisfies a balance condition for each industry/commodity. The c-th column sum of V1BAS, V1MAR, V1TAX, LABOR, CAPITAL, LAND and V0TAX, that is the value of inputs to the c-th industry, equals the basic value of sales of the c-th commodity (the product of the c-th industry). If c is a non-margin commodity, then the basic value of sales of the domestic variety of the c-th commodity is the sum across the (c,“dom”)-rows of V1BAS1 to V6BAS. If c is a margin commodity, then the basic value of sales of the domestic variety of c is the direct uses, i.e., the sum across the (c,“dom”)-rows of V1BAS to V6BAS, plus the margins use of commodity c. The margins use of c is the sum of the components in the (k,s,c)-rows of V1MAR to V6MAR for all commodities k and sources s.

By forming the sum of all inputs to domestic production and the sum of the basic value of sales of all domestic commodities, and then applying the input-output balance conditions we see that:

$$\begin{aligned}
&\mathrm{Sum(V1BAS)} + \mathrm{Sum(V1MAR)} + \mathrm{Sum(V1TAX)} + \mathrm{Sum(LABOR)} + \mathrm{Sum(CAPITAL)} \\
&\quad + \mathrm{Sum(LAND)} + \mathrm{SUM(V0TAX)} \qquad (1)\\
&\quad = \sum_{b=1}^{6} \mathrm{Sum(V\,b\,BAS)} + \sum_{b=1}^{6} \mathrm{Sum(V\,bMAR)} - \sum_{\substack{b=1\\ b\neq 4}}^{6} \mathrm{Sum(V\,b\,BAS(imp))}
\end{aligned}$$

where

the notation Sum(matrix) means the sum of all components of matrix,
VbBAS(imp) refers to the import components of VbBAS, and
we assume that there are no imported commodities that are simply re-exported, that is we rule out V4BAS(imp).

Cancelling common terms from the left- and right-hand sides of (1) and bringing in additional tax terms to both sides leads to:

$$\begin{aligned}
&\mathrm{Sum(LABOR)} + \mathrm{Sum(CAPITAL)} + \mathrm{Sum(LAND)} \\
&\quad + \sum_{b=1}^{6} \mathrm{Sum(VbTAX)} + \mathrm{SUM(V0TAX)} + \mathrm{Sum(TARIFF)} \\
&\quad = \mathrm{Sum(V\,2\,BAS)} + \mathrm{Sum(V\,2TAX)} + \mathrm{Sum(V\,2MAR)} \\
&\qquad + \mathrm{Sum(V\,3\,BAS)} + \mathrm{Sum(V\,3TAX)} + \mathrm{Sum(V\,3MAR)} \\
&\qquad + \mathrm{Sum(V\,4\,BAS)} + \mathrm{Sum(V\,4TAX)} + \mathrm{Sum(V\,4MAR)} \qquad (2)\\
&\qquad + \mathrm{Sum(V\,5\,BAS)} + \mathrm{Sum(V\,5TAX)} + \mathrm{Sum(V\,5MAR)} \\
&\qquad + \mathrm{Sum(V\,6\,BAS)} + \mathrm{Sum(V\,6TAX)} + \mathrm{Sum(V\,6MAR)} \\
&\qquad - \left[\sum_{\substack{b=1\\ b\neq 4}}^{6} \mathrm{Sum(V\,b\,BAS(imp))} - \mathrm{Sum(TARIFF)} \right]
\end{aligned}$$

which is the GDP identity. The left-hand side is GDPINC, that is GDP as income, consisting of payments to factors of production *plus* indirect taxes. The right-hand side is GDPEXP, that is GDP as expenditure, consisting of investment, private consumption, exports, public consumption and inventory accumulation all valued at purchasers prices, *less* imports valued at c.i.f prices (landed-duty-paid *less* tariffs). Equation (2) is not only of interest as the foundation of national income accounting, but it also plays an important checking role in CGE modeling. If equation (2) is violated by results from a simulation, then we are alerted to the existence of an error.

2.2. Moving off the starting point

The components of Figure 1 move in response to shocks to exogenous variables such as changes in technologies, preferences, world commodity prices and taxes. As the components move, demand and supply equations and zero-profit equations maintain the balance for each commodity between the basic values of costs and sales. The movements in the individual components of Figure 1 are combinations of price and quantity movements. Price movements are driven by costs reflecting production technologies and scarcities of primary factors. Quantity movements are governed by optimizing behavior: industries choose input and output quantities to maximize profits; investors choose input quantities to minimize the costs of creating units of capital; and households choose consumption quantities to maximize utility.

Reflecting the emphasis in CGE models on movements, CGE equations are often most easily understood in change or percentage change form. For example, many CGE models handle the demand for primary factors via equations of the form:

$$\mathrm{xfac(n,j)} - \mathrm{afac(n,j)} = \mathrm{x0output(j)} + \mathrm{aprim(j)} - \sigma\mathrm{fac(j)} * \left(\mathrm{pfac(n,j)} - \sum_k \mathrm{SFAC(k,j)} * \mathrm{pfac(k,j)} \right)$$
$$- \sigma\mathrm{fac(j)} * \left(\mathrm{afac(n,j)} - \sum_k \mathrm{SFAC(k,j)} * \mathrm{afac(k,j)} \right) \qquad (3)$$

where

σfac(j) is a positive parameter denoting the elasticity of substitution between primary factors in industry j;
SFAC(k,j) is the share of factor k in the total cost of primary factors to industry j which can be calculated from input-output data; and
xfac(n,j), x0output(j), pfac(k,j), aprim(j) and afac(k,j) are all percentage changes in variables away from their values in an initial situation represented by a database such as Figure 1.
xfac(n,j) is the percentage change in the demand for factor n to be used in industry j;
x0output(j) is the percentage change in the output of industry j[6];
pfac(k,j) is the percentage change in the price of factor k to industry j; and
aprim(j) and afac(k,j) are primal-factor-saving and factor-k-saving technical change in industry j, expressed as a percentage.[7]

By looking at (3) we can immediately identify three assumptions that have been made about the production function for industry j. First, the absence of intermediate input prices on the right-hand side of (3) implies that primary factors and intermediate inputs are being treated as non-substitutes.[8] Second, the implicit coefficient of one on x0output(j) implies constant returns to scale in the formation of the composite primary-factor input to industry j: if there are no changes in factor prices or technologies then demands for factors move in line with output. Third, the absence of an n argument on σfac(j) means that the elasticity of substitution between all pairs of primary factors has the same value, implying that the underlying production function must be of the CES form. Of course, these assumptions can be varied, but whatever assumptions are adopted, their implications are often transparent in percentage change equations.

Other typical CGE equations include

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[6] As implied by equation (3), x0output(j) is a weighted average of the percentage changes in inputs of primary factors to industry j modified by technical changes: $\mathrm{x0output(j)} = \sum_k \mathrm{SFAC(k,j)} * [\mathrm{xfac(k,j)} + \mathrm{afac(k,j)}] - \mathrm{aprim(j)}$.

[7] Equation (3) can be derived from a cost-minimizing problem of the form: Choose XFAC(k,j) for all k to minimize $\sum_k \mathrm{PFAC(k,j)} * \mathrm{XFAC(k,j)}$ subject to $\mathrm{XOUTPUT(j)} = \frac{1}{\mathrm{APRIM(j)}} * \mathrm{CES}_k \left(\frac{\mathrm{XFAC(k,j)}}{\mathrm{AFAC(k,j)}} \right)$ where the uppercase symbols, PFAC, XFAC etcetera, refer to the levels of the variables denoted by the corresponding lowercase symbols in (3).

[8] As we will see in section 3, substitution between intermediate and primary-factor inputs is allowed in NCAER-VU. This leads to additional price terms in input-demand functions such as (3).

$$\begin{aligned} p0dom(c) = &\sum_{v,s} R1(v,s,c) * p1(v,s,c) + \sum_{k} RFAC(k,c) * pfac(k,c) \\ &+ \sum_{v,s} R1(v,s,c) * a1(v,s,c) + \sum_{k} RFAC(k,c) * \left[afac(k,c) + aprim(c)\right] \end{aligned} \tag{4}$$

and

$$\begin{aligned} &x0output(c) = \sum_{j} T1(c,dom,j) * x1(c,dom,j) + \sum_{j} T2(c,dom,j) * x2(c,dom,j) \\ &+ T3(c,dom) * x3(c,dom) + T4(c) * x4(c) + T5(c,dom) * x5(c,dom) + T6(c,dom) * x6(c,dom) \\ &+ \sum_{j}\sum_{s}\sum_{k} TMAR_{j}(k,s,c) * xmar_{j}(k,s,c) \end{aligned} \tag{5}$$

In (4), the percentage change in the basic price of domestically produced commodity c [p0dom(c)] is determined by the percentage changes in input prices [p1(v,s,c) and pfac(k,c)] to the production of c and by technical changes [a1(v,s,c), aprim(c) and afac(k,c)] affecting inputs per unit of output of c. In (5) the percentage change in the output of c [x0output(c)] is determined by percentage changes in direct demands and margin demands. Direct demands are made: by industries which use domestic c as an input to production and capital creation [x1(c,dom,j) and x2(c,dom,j)]; by households [x3(c,dom)]; by foreigners [x4(c)]; by government [x5(c,dom)]; and by inventory accumulators [x6(c,dom)]. If c is a margin commodity then further demands arise from the use of c to facilitate the flow of commodity k from source s to user j [$xmar_j$(k,s,c)]. The R coefficients in (4) are shares of each input in total costs of production in industry c, and the T coefficients in equation (5) are shares of each demander in the total sales of domestic commodity c. Both the R and T coefficients are calculated from the input-output data in Figure 1.

A detailed CGE model such as NCAER-VU has hundreds of thousands of equations. In addition to equations such as (3) to (5), there must be equations to define: demands for intermediate inputs to current production and capital creation; demands by final users (households, exports, government, inventory accumulation); and margin demands. There must be equations to link purchasers prices [such as the p1's appearing on the right-hand side of (4)] to sales taxes, the costs of margins and basic prices [such as p0dom on the left-hand side of (4)]. There must be market-clearing equations not only for commodities [illustrated by (5)] but also for primary factors. So that results can be reported conveniently, there must be defining equations for a wide range of macro variables such as the expenditure components of GDP (C, I, G, X and M), the income components of GDP (factor payments and indirect taxes), the price level, the average wage rate, the balance of trade and the public sector deficit. While CGE models have huge numbers of equations, when expressed in linear percentage-change form these are easily interpreted.

The linear percentage change form also facilitates computation. The linear equations can be written as

$$A * v = 0 \tag{6}$$

where v is the vector of percentage changes in variables [the x's, a's and p's in equations such as (3) to (5)] and A is a matrix of coefficients containing shares [e.g. the SFAC's in (3),the R's in (4) and the T's in (5)], parameters [e.g. σfac in (3)] and many zeros and ones. The dimensions of A are mxn where m is the number of equations and n is the number of variables which is always greater than m. To solve (6) we must choose m variables to be endogenous and n-m variables to be exogenous. CGE modellers gain flexibility by varying this choice between applications. For example, in some applications it is appropriate to fix aggregate employment exogenously and determine market-clearing wage rates endogenously. In other applications it is appropriate to fix wage rates exogenously and determine employment endogenously. Once the endogenous/exogenous choice (closure) is made, then CGE software such as GEMPACK[9] rearranges (6) as

$$A_1 * v_1 + A_2 * v_2 = 0 \tag{7}$$

where

v_1 is the vector of percentage changes in the m variables chosen to be endogenous,

v_2 is the vector of percentage changes in the remaining n-m variables which are exogenous, and

A_1 and A_2 are the mxm and mx(n-m) matrices formed from the columns of A corresponding to the endogenous and exogenous variables.

From (7), GEMPACK computes percentage changes in endogenous variables for given percentage changes in exogenous variable according to[10]:

$$v_1 = -A_1^{-1} * A_2 * v_2 \tag{8}$$

Linearization errors can be avoided by imposing the changes in the exogenous variables in a series of steps.[11] For example, if we want to know the effects of a 50 per cent increase in a tax rate, then we could proceed by: (a) computing the effects of a 25 per cent increase using the linear system (8); (b) updating all the flows in Figure 1 to reflect the situation after the 25 per cent increase; (c) re-evaluating share coefficients such as those in (3) to (5); (d) reassembling the A_1 and A_2 matrices; and (e) reapplying (8) to compute the effects of the remainder of the 50 per cent tax increase. In practice, the effects of quite large changes in exogenous variables can often be computed without noticeable linearization error in just a few steps.

2.3. General purpose modifications of published input-output data for India

The latest comprehensive input-output data published by India Statistics (IS) are for 2007-08. They disaggregate the Indian economy into 130 industries. Before using these data in NCAER-VU we aggregated the IS industries Jowar, Bajra and Maize into an industry that we named Coarse cereals, and we aggregated the IS industries Ground nuts and Other oil seeds into an industry that we named Oil seeds. As we will see in subsection 2.3(b), this facilitated the use of relevant non-input-output data. After the aggregations were completed our version of the IS input-output tables had 127 industries.

The form in which the IS input-output data are published is indicated in Figure 2. Consistent with our description of Figure 1, in the IS input-output data each industry produces a single commodity and each commodity is produced by a single industry. Also, as in Figure 1, the IS data satisfy the input-output balance condition for each commodity: the c-th column sum of V1, V1T, GVA equals the c-th row sum of V1 to V6 minus V7, that is industry outputs equal sales of domestically produced commodities. However, from the point of view of CGE modelling, the IS published data have the following problems and limitations.

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[9] See Horridge *et al*. (2013) and Harrison *et al.* (2014).

[10] This method was introduced in the seminal CGE work of Johansen (1960).

[11] This method was introduced by Dixon *et al*. (1982) and later embedded in GEMPACK, see Pearson and Codsi (1991).

Figure 2. Input-Output Database published by India Statistics

		Absorption Matrix						
		1	2	3	4	5	6	7
		Prod-ucers	Invest-ors	House-holds	Exports	Govern-ment	Invent-ories	-Imports (cif)
	Size	← I →	← 1 →	← 1 →	← 1 →	← 1 →	← 1 →	← 1 →
Flows: Dom, basic +Imp, cif	↑ C ↓	V1	V2	V3	V4	V5	V6	-V7
Sales taxes + tariffs	↑ 1 ↓	V1T	V2T	V3T	V4T	V5T	V6T	0
Gross value added	↑ 1 ↓	GVA						
Output	↑ 1 ↓	VOUTPUT						

C = Number of commodities
I = Number of industries

2.3(a). The IS data shows negative entries for flows of some commodities to intermediate users and to households.

These negative entries are incompatible with the theory of the NCAER-VU model and if retained in the database would cause computational problems.

In total there are 11 illegitimate negative entries: 7 in intermediate flows to current production and 4 in flows to households. All of these are small. The largest negative intermediate flow is -0.038m Rs (for Business services to the Raw jute industry) and the largest negative flow to households is -0.017m Rs (for Raw jute). We assumed that these flows should be zero, and zeroed them out. Then we made compensating subtractions from inventory accumulations (which can legitimately be negative), leaving commodity sales unchanged. In the case of the flows to current production we made compensating reductions to primary factor inputs, leaving industry outputs unchanged. In this way, we maintained the balance of the input-output data.

Another similar problem we noticed was that for 5 commodities, imports in the IS data (column 7 of Figure 2) exceed the total of non-inventory sales of the domestic and imported varieties of the commodity to domestic agents (the sum of the c-th row of V1, V2, V3, and V5 is less than the c-th entry in V7). This would be possible if there were sufficient negative accumulation of imported inventories. But we don't think this is what is happening, especially as some of the commodities in question are services. In any case, we don't allow for imported inventories. We have eliminated the problem be reducing imports of these 5 commodities in the V7 vector and making compensating downward adjustments to exports, thus preserving input-output balance.

2.3(b). The IS data provide a single row for value added

There is no disaggregation of value added into labour, capital, land and production taxes/subsidies.

A disaggregation of gross value added (GVA) is available in the India component of the 57-industry GTAP database (https://www.gtap.agecon.purdue.edu/databases/v8/default.asp). We mapped our 127 IS industries to the 57 GTAP industries and then used the GTAP disaggregation to provide a labour/capital/land disaggregation for each of the 127 IS industries. The focus of the NCAER-VU application reported in section 3 is agriculture. As can be seen from Table 1, GTAP provides a good basis for disaggregating GVA for the main agricultural products in the IS input-output data. GTAP identifies as separate products Paddy, Wheat, Cereals nec, Sugar crops, and Oil seeds thereby giving an unambiguous basis for disaggregating GVA for the corresponding IS industries. For the IS industries Fruits, Vegetables, Coarse cereal, Jute and Cotton the corresponding GTAP industries also appear to be close fits.

We created a production tax/subsidy row but at this stage we populated it with zeros.

2.3(c). For investment, the IS data give a single column showing investment expenditure by commodity

There is no industry dimension as required for the ideal database in Figure 1.

We converted the V2, V2T vector into a matrix with *I* columns by assuming that investment expenditures on each commodity in each industry are proportional to the industry's returns to capital (CAPITAL in Figure 1). Under this approach, the investment expenditure of each industry has the same commodity composition. This assumption is far

Table 1. GTAP industries used in disaggregating gross value added of IS agricultural industries

IS agriculture industries after aggregations to form Coarse cereals and Oil seeds	Corresponding GTAP industry
Paddy	Paddy
Wheat	Wheat
Coarse cereals	Cereals nec
Gram	Cereals nec
Pulses	Cereals nec
Sugarcane	Sugar crops
Oil seeds	Oil seeds
Coconut	Crops nec
Jute	Plant-based fibers
Cotton	Plant-based fibers
Tea	Crops nec
Coffee	Crops nec
Rubber	Crops nec
Tobacco	Crops nec
Fruits	Vegetables, fruits, nuts
Vegetables	Vegetables, fruits, nuts
Other Crops	Crops nec
Milk Products	Animal products
Animal Services	Animal products
Poultry and eggs	Other animal products
Other live stock	Animal products

from ideal. It ignores obvious facts such as investment expenditures by agricultural industries are intensive in tractors while those of Rail transport are intensive in Railroad equipment. The application reported in section 3 is comparative static (single period). With investment playing rather a minor role, our current crude treatment of the composition of investment expenditures is not a major problem. However, for future dynamic applications this will need to be rectified.

2.3(d). The published IS data treat net indirect taxes (taxes less subsidies) as a single row

The components in this row are net indirect taxes paid on all purchases by the using agent (industries for current production, investment, households, exports, government and inventory accumulation). The taxes include tariffs on imported inputs. This is consistent with the cif valuation of imports in the IS data. Relative to the ideal database in Figure 1, the IS tax data are missing the commodity dimension and separate identification of tariffs on imports.

The missing commodity dimension was supplied through unpublished data from IS. These data contained 130 commodity components (which we aggregated to 127) for each entry in V1T to V6T. We found inconsistences between the disaggregated IS tax/subsidy data and the flow data in V1 to V6. In a few cases there were small taxes on zero flows to current production. In these cases we simply zeroed out the tax and added it to a significant tax collection in the same column. More serious problems occurred in the disaggregation of consumption taxes. For 31 commodities the IS data showed significant taxes/subsidies on zero flows. On inquiry it was determined that taxes/subsidies assigned to flows to households should have been applied to households and exports. We split all of the taxes/subsidies given in the original IS data for households across households and exports according to the flows in V3 and V4 vectors. Thus we assumed the same rate of tax/subsidy on flows to households and exports. Superficially this seems an unsatisfactory assumption. However, in most cases with large tax flows, the flow to one or other of households or exports was dominant, telling us where the bulk of the combined tax should be assigned.

As well as disaggregated tax data, IS supplied an unpublished tariff vector.

2.3(e). The IS data show imports valued at c.i.f. as a single column in the final demand section

In Figure 2, flows of commodities to users are a combination of domestic goods valued at basic prices and imported goods valued at cif prices. As shown in Figure 1 we require separate identification of domestic and import flows for each commodity to each user valued at basic prices. We also require a tariff vector.

To meet these requirements we started by calculating the share of cif imports for each commodity c in the total sales of c recorded in V1, V2, V3 and V5. Then we deducted this share from each of these sales to reveal the basic value of sales of the domestic commodity. These were recorded in the (c,dom) row of V1BAS, V2BAS, V3BAS and V5BAS. The deducted cif imports were placed in the (c,imp) row. As mentioned in subsection 2.3(d), we obtained an unpublished tariff vector from India Statistics. This enabled us to calculate the tariff rate for each commodity c. Using this rate we converted the cif imports in the (c,imp) row of V1BAS, V2BAS, V3BAS and V5BAS to basic values (landed duty paid). Next we deducted the tariff collection that we had just added to the cif imports from the c-row of V1T, V2T, V3T and V5T. Finally we split these tax matrices into domestic and import components assuming a common rate of sales tax.

2.3(f). The IS data do not identify margin flows

Margin and direct use of Rail transport, for example, are shown in the IS data in a single row of V1 to V6. From the point of view of CGE modelling, this presents two problems. First, we don't know what proportion of any cell is margin use (Rail services for facilitating the flows of commodities to the user identified in the column) and what proportion is direct use (Rail services used for passengers). Second, we don't know which commodities flowing to a particular user attract Rail transport margin services. Absence of margin data limits our ability to conduct simulations in which differences between basic prices and purchasers prices are important. For example, in simulating the effects of a tariff increase applying to the cif price of Jewelry we need to calculate the effects on the purchasers' price to households. This depends on the share in the purchasers' price of the cif import price, which could be quite small when warehousing, transport and retail margins are taken into account. Absence of margin data also limits our ability to project the effects of policy and other shocks on demands for margin services. For example, we might wish to know how Rail requirements would be affected by increases in exports of Iron ore. This question is unanswerable without information on the margin use of Rail services in facilitating exports of Iron ore.

At this stage in the development of the NCAER-VU model we have included demands for margins in the computer representation of the model. We have also included V1MAR, …, V6MAR matrices in the data files. However these matrices currently contain only zeros. In effect all of the demands for Rail transport, Road transport etc are treated as direct demands. Introduction of genuine margin demands should have high priority in future work on this project.

2.4. Special purpose modifications of published input-output data for India

Confronted with a particular policy issue, it is rare for a CGE model to be ready off the shelf to tackle it. Almost always we need to modify the database or the underlying theory or both. As explained in subsection 2.3, we implemented NCAER-VU with the 127-industry input-output data for 2007-8 published by India Statistics. For our illustrative application in section 3 we simulate the effects of removal of agricultural subsidies. To facilitate this application we modified the agricultural sector in the initial version of NCAER-VU in three ways: by eliminating diagonal flows of domestic agricultural commodities; by splitting 6 agricultural industries into sub industries; and by splitting agricultural land by region.

2.4(a) Eliminating diagonal flows for agricultural industries

For several agricultural industries, the IS input-output data show large diagonal flows. For example, the Paddy to Paddy flow in V1 (see Figure 2) accounts for 32% of total Paddy industry costs (VOUTPUT in Figure 2), and the Wheat to Wheat flow accounts for 17% of total Wheat industry costs. On enquiry we found that the diagonal elements are largely milling activities. The Paddy industry in the IS data refers not only to the activity of growing Paddy but also to the milling of rice. The Paddy to Paddy sale is the sale of raw paddy to rice mills, and the paddy sales outside the Paddy industry are sales of milled rice. Similarly, the Wheat to Wheat sale is the sale of raw wheat to wheat mills and the Wheat sales outside the Wheat industry are sales of milled wheat. We noted that some of the diagonal sales are accompanied by large subsidies.

A problem with leaving the subsidy on the Paddy/Paddy flow is that a simulation of the effects of removing subsidies could show a spurious reduction in Paddy input per unit of Paddy output, implying a spurious reduction in milling activity. In subsections 2.4(b) and 2.4(c), we introduce multiple paddy industries with a regional dimension. This raises a second problem with Paddy/Paddy flows: if they were left in, then our model could imply spurious flows of Paddy produced in one region to milling in another region. To minimize the possibility of these spurious substitution effects, we eliminated the domestic components of the diagonal flows, reallocated the diagonal sales subsidies as negative entries in the production-tax row (V0TAX), and adjusted VOUTPUT. In effect, these adjustments form an integrated Paddy-growing-milling industry, an integrated Wheat-growing-milling industry, etc, industries with non-negligible production subsidies that produce lightly processed agricultural products (not raw products).

2.4(b) Allowing for different technologies and subsidy rates within 6 agricultural industries

We aimed to create a version of NCAER-VU capable of showing different dependences on agricultural subsidies across regions of India.

The data we used in moving toward this objective are set out in Tables 2 and 3. The data in Table 2 provide a basis for disaggregating six agricultural industries (Paddy, Wheat,

Table 2. Output, input and subsidy data for agricultural industries

Industry	Output Rs m[1]	Share in output of aggregate industry	Fertilizer input Rs m	Share in flow of Fertilizer to aggregate industry	Subsidy on Fertilizer Rs m	Subsidy rate on Fertilizer	Electricity input Rs m	Share in flow of Electricity to aggregate industry	Subsidy on Electricity Rs m	Subsidy rate on Electricity	Production subsidy Rs m	Production subsidy rate	Subsidy on sales Rs m	Subsidy rate on sales	Total subsidy Rs m	Total subsidy rate
	(1)	(2)	(3)	(4)	(5)	(6)[2]	(7)	(8)	(9)	(10)[3]	(11)	(12)[4]	(13)	(14)[5]	(15)[6]	(16)[7]
Paddy1	1028505	0.7838	83657	0.7374	39908	47.7	84025	0.7846	52573	62.6	56661	5.5	122707	11.9	271849	26.4
Paddy2	215059	0.1639	21416	0.1888	10217	47.7	17547	0.1638	10979	62.6	11726	5.5	25658	11.9	58580	27.2
Paddy3	68667	0.0523	8379	0.0739	3997	47.7	5523	0.0516	3456	62.6	3698	5.4	8192	11.9	19343	28.2
Wheat1	298390	0.3298	25752	0.3277	12285	47.7	21828	0.3304	15901	72.8	16317	5.5	81614	27.4	126117	42.3
Wheat2	422329	0.4668	37821	0.4812	18042	47.7	30808	0.4663	17420	56.5	22760	5.4	115514	27.4	173736	41.1
Wheat3	120695	0.1334	12707	0.1617	6062	47.7	8812	0.1334	5994	68.0	6505	5.4	33012	27.4	51574	42.7
Wheat4	63415	0.0701	2316	0.0295	1105	47.7	4616	0.0699	2020	43.8	3486	5.5	17345	27.4	23955	37.8
CoarsCereal1	35111	0.1270	4185	0.1541	1996	47.7	1365	0.1269	851	62.4	38	0.1	1719	4.9	4605	13.1
CoarsCereal2	75711	0.2739	6521	0.2401	3111	47.7	2947	0.2739	2251	76.4	83	0.1	3708	4.9	9153	12.1
CoarsCereal3	35394	0.1281	4670	0.172	2228	47.7	1376	0.1279	783	56.9	38	0.1	1733	4.9	4782	13.5
CoarsCereal4	130176	0.4710	11783	0.4338	5621	47.7	5073	0.4714	2848	56.1	142	0.1	6375	4.9	14986	11.5
Gram	127505		6026		2875	47.7	4238		2651	62.6	732	0.6	7886	6.2	14144	11.1
Pulses	448667		15087		7197	47.7	4027		2520	62.6	160	0.0	541	0.1	10418	2.3
Sugarcane1	38331	0.1092	5897	0.1997	2813	47.7	1499	0.1089	1378	92.0	420	1.1	6291	16.4	10902	28.4
Sugarcane2	135615	0.3863	14320	0.4849	6831	47.7	5314	0.3863	3304	62.2	1507	1.1	22257	16.4	33900	25.0
Sugarcane3	38527	0.1097	806	0.0273	385	47.7	1513	0.11	999	66.0	449	1.2	6323	16.4	8156	21.2
Sugarcane4	138590	0.3948	8508	0.2881	4059	47.7	5432	0.3948	2926	53.9	1573	1.1	22745	16.4	31304	22.6
OilSeeds1	118074	0.1973	6835	0.1607	3261	47.7	1253	0.1976	872	69.6	481	0.4	3846	3.3	8461	7.2
OilSeeds2	391019	0.6536	28364	0.667	13531	47.7	4146	0.6536	2580	62.2	1580	0.4	12738	3.3	30429	7.8
OilSeeds3	68918	0.1152	7089	0.1667	3382	47.7	727	0.1146	463	63.8	274	0.4	2245	3.3	6364	9.2
OilSeeds4	20288	0.0339	238	0.0056	114	47.7	217	0.0343	53	24.5	84	0.4	661	3.3	912	4.5
Coconut	71020		3141		1498	47.7	1		1	62.6	1	0.0	123	0.2	1622	2.3
Jute	19422		1541		735	47.7	0		0	62.6	0	0.0	0	0.0	735	3.8

Table 2 continues …

Table 2 continued …

Industry	Output Rs m[1]	Share in output of aggregate industry	Fertilizer input Rs m	Share in flow of Fertilizer to aggregate industry	Subsidy on Fertilizer Rs m	Subsidy rate on Fertilizer	Electric ity input Rs m	Share in flow of Electricity to aggregate industry	Subsidy on Electricity Rs m	Subsidy rate on Electricity	Prod- uction subsidy Rs m	Prod- uction subsidy rate	Subsidy on sales Rs m	Subsidy rate on sales	Total subsidy Rs m	Total subsidy rate
	(1)	(2)	(3)	(4)	(5)	(6)[2]	(7)	(8)	(9)	(10)[3]	(11)	(12)[4]	(13)	(14)[5]	(15)[6]	(16)[7]
Cotton1	48021	0.1640	3163	0.1101	1509	47.7	2230	0.1642	1595	71.5	90	0.2	10190	21.2	13384	27.9
Cotton2	133253	0.4550	12730	0.4431	6073	47.7	6177	0.4548	4040	65.4	244	0.2	28277	21.2	38633	29.0
Cotton3	100170	0.3420	10650	0.3707	5081	47.7	4650	0.3423	2584	55.6	182	0.2	21256	21.2	29103	29.1
Cotton4	11428	0.0390	2186	0.0761	1043	47.7	525	0.0386	280	53.3	20	0.2	2425	21.2	3768	33.0
Tea	37585		1295		618	47.7	0		0	62.6	0	0.0	1203	3.2	1821	4.8
Coffee	27440		0		0	47.7	0		0	62.6	0	0.0	369	1.3	369	1.3
Rubber	70807		4012		1914	47.7	0		0	62.6	0	0.0	2	0.0	1916	2.7
Tobacco	25569		3749		1788	47.7	1735		1086	62.6	6	0.0	2406	9.4	5286	20.7
Fruits	654907		9615		4587	47.7	5353		3349	62.6	-41	0.0	-2427	-0.4	5469	0.8
Vegetables	851418		14088		6721	47.7	6450		4035	62.6	-5	0.0	-366	0.0	10386	1.2
OtherCrops	1093746		68849		32844	47.7	36522		22851	62.6	2311	0.2	180188	16.5	238194	21.8
MilkProds	1651590		0		0	47.7	0		0	62.6	-5	0.0	-8171	-0.5	-8176	-0.5
Total or ave	8815360		447400		213428	47.7	275929		172646	62.6	131520	1.5	738587	8.4	1256181	14.2

1. The values in this column are from the NCAER-VU 2007-8 database after elimination of diagonal flows in agriculture, see subsection 2.4(a).
2. Calculated as 100 times column (5) divided by column (3).
3. Calculated as 100 times column (9) divided by column (7).
4. Calculated as 100 times column (11) divided by column (1).
5. Calculated as 100 times column (13) divided by column (1).
6. Calculated as sum of columns (5), (9), (11) and (13).
7. Calculated as 100 times column (15) divided by column (1).

Coarse cereals, Sugarcane, Oil seeds and Cotton[12]): the Paddy industry into three sub-industries named in Table 2 as Paddy1, Paddy2 and Paddy3; the Wheat industry into four sub-industries, named in Table 2 as Wheat1, Wheat2, Wheat3 and Wheat4; etc.

Splitting the industries allows us to recognize that a given crop is grown in different parts of India with different Electricity and Fertilizer inputs per unit of output. For example, Sugarcane1, which is grown in Tamil Nadu (see Table 3), accounts for 19.97 per cent of national Fertilizer use in the production of Sugarcane [Table 2, column (4)] but only 10.92 per cent of Sugarcane output [column (2)]. Sugarcane2, grown in Maharashtra, Karnataka and Andhra Pradesh, also uses a Fertilizer-intensive technology: it accounts 48.49 per cent of fertilizer use in Sugarcane [column (4)] but only 38.63 per cent of output [column (2)]. By contrast Sugarcane3 and Sugarcane4 are light users of Fertilizer. Relative to the variation for Fertilizer use, the data in Table 2 show little variation between technologies for any given crop in Electricity use. For example, Paddy1 accounts for 78.46 per cent of Electricity use in Paddy production [column (8)] and 78.38 per cent of output [column (2)].

Table 2 reveals no differences across agricultural activities in the rate of Fertilizer subsidy. In every case the subsidy rate is 47.7 per cent, that is, Fertilizer with a basic value of Rs 100 costs the farmer Rs 52.3 [Table 2, column (6)]. For Electricity, the subsidy rates vary between 24.5 per cent and 92.0 per cent with an average over all the crops shown in Table 2 of 62.6 per cent [column (10)].

Columns (11) and (12) of Table 2 show production subsidies and production-subsidy rates. The production subsidies in our database were generated when we eliminated diagonal flows, see subsection 2.4(a). The subsidy rates on production vary from 0 to 5.5 per cent. Columns (13) and (14) show subsidies on sales and rates of sales subsidies. For each agricultural industry, sales subsidies are the total of subsidies on sales of the industry's commodity to other industries and to public and private consumption.[13] The subsidy rates on sales vary from 0 to 27.4 per cent.

Column (15) in Table 2 shows the total for each industry of Fertilizer, Electricity, production and sales subsidies. In column (16) we express these totals as percentages of industry outputs, which we refer to as total subsidy rates. These total subsidy rates vary from -0.5 per cent to 42.7 per cent, and average 14.2 per cent.

To take advantage of the data in Table 2, we return to Figure 1 and split the Paddy industry/commodity into 4 industries/commodities: Paddy1, Paddy2, Paddy3 and Paddy. The Paddy1 industry uses a technology (has a column structure for its input flows) reflecting the Fertilizer and Electricity data in Table 2 and produces a commodity that we call Paddy1. Similarly, the Paddy2 and Paddy3 industries use technologies reflecting the data in Table 2 and produce commodities that we call Paddy2 and Paddy3. To handle the sales of Paddy1, Paddy2 and Paddy3, we convert the original Paddy industry into a mixing industry which buys all of the output of Paddy1, Paddy2 and Paddy3 and has no other inputs. This leaves the total value of inputs to the new mixing Paddy industry exactly the same as in the original Paddy industry. The sales row for the mixed Paddy commodity is unaltered from the sales row for (Paddy,domestic) in V1BAS to V6BAS.[14] We followed a similar approach for Wheat, Coarse cereals, Sugarcane, Oil seeds and Cotton. In each of the mixing industries we

[12] It was so that we could use these data that we formed the aggregated Coarse cereals and Oil seeds industries, see subsection 2.3.

[13] In calculating sales subsidies we did not distinguish between domestic and imported commodities. Imports of agricultural commodities are small.

[14] The Paddy row is unchanged from the situation it reached after the elimination of the (Paddy, Paddy) flow.

adopt a high substitution elasticity between inputs. For example, we assume that Paddy1, Paddy2 and Paddy3 are very good substitutes in the creation of the mixed good, Paddy, which is sold to the rest of the economy. If the price of Paddy1 rises relative to the prices of Paddy2 and Paddy3, then our treatment of substitution in the Paddy mixing industry ensures in the model that output of Paddy1 contracts relative to that of Paddy2 and Paddy3.

More technically, we introduce the sub-industries and mixing industries into the NCAER-VU database in 3 steps.

Step 1. Create 23 new agricultural industries

We add 23 columns of zeros to V1BAS, V1MAR, V1TAX, …, VOUTPUT. These are labeled Paddy1, Paddy2, Paddy3, Wheat1 to Wheat4, Coarse cereals1 to Coarse cereals4, etc.

Step 2. Use the data in Table 2 to fill in Electricity, Fertilizer flows and associated sales tax entries together with output for the 23 new agricultural industries

For each row of V1BAS, V1MAR, …, VOUTPUT we decide what shares (adding to 1) of the original Paddy entry to shift to Paddy1, Paddy2 and Paddy3. For V1BAS(Electricity, s, Paddy), s = dom and imp, the shares are 0.7846 to Paddy1, 0.1638 to Paddy2, and 0.0516 to Paddy3, see column (8) in Table 2. For V1BAS(Fertilizer, s, Paddy) the shares are 0.7374, 0.1888 and 0.0739, see column (4) in Table 2. . For VOUTPUT(Paddy) the shares are 0.7838, 0.1639 and 0.0523, see column (2) in Table 2. For V1TAX(Electricity, s, Paddy) and for V1TAX(Fertilizer, s, Paddy) we compute the shares on the basis of columns (9) and (5).

For Paddy1, Paddy2 and Paddy3, we calculate the residual value of inputs. This is VOUTPUT(Paddyi) less what we have allocated in the Paddyi column to Electricity and Fertilizer flows and associated taxes. We add up the residual value of inputs to the three Paddy sub-industries and calculate the Paddyi share in this total residual. Applying these Paddyi shares for i = 1, 2, and 3, we distribute all remaining entries in the original Paddy column to Paddy1, Paddy2 and Paddy3.

We follow a similar procedure for Wheat, Coase cereals etc.

Step 3. Create 23 new commodities

We start by adding 46 rows (23 commodities by two sources) of zeros to V1BAS, V2BAS, …, V6BAS. Then we record: VOUTPUT(Paddy1) in the (Paddy1,dom,Paddy)-entry of V1BAS; VOUTPUT(Paddy2) in the (Paddy2,dom,Paddy)-entry of V1BAS; VOUTPUT(Paddy3) in the (Paddy3,dom,Paddy)-entry of V1BAS; VOUTPUT(Wheat1) in the (Wheat1,dom,Wheat)-entry of V1BAS; etc.

So that we don’t have to alter the algebraic specification of the model by making special cases, we add corresponding zero rows to V1MAR, …, V6MAR and to V1TAX, …, V6TAX, but these zeros are never changed. There are no taxes or margins on the artificial flows of the sub-commodities to the artificial mixing industries.

2.4(c) Introducing competition between agricultural industries for land

At this stage we have a balanced database with 150 industries and commodities (rather than the 127) but no disaggregation of land: in terms of Figure 1, T is currently equal to one. With only one row showing inputs of land for each industry, we cannot identify adequately competition between different crops for various types of land. We use the data in Table 3 to

Table 3. Value of outputs in agricultural industries by land type

Land type (τ) / ***Agricultual activity (k)***	1 Punjab	2 Haryana	3 Gujarat	4 UttarPradesh	5 Rajasthan	6 Bihar	7 MadhyaPrad	8 WestBengal	9 Uttarakhand	10 JamKashmir	11 Maharashtra	12 Jharkhand
1 Paddy1	164861	68492	30196	279844	0	121208	15709	175751	0	0	27786	5873
2 Paddy2	0	27	7463	17130	0	21963	27245	48620	0	0	20283	35760
3 Paddy3	206	0	0	10349	0	13138	4379	17527	0	0	5734	3112
4 Wheat1	218369	142246	0	0	0	0	0	0	0	0	0	0
5 Wheat2	0	0	53369	356907	98956	0	0	0	0	0	0	0
6 Wheat3	0	0	0	0	0	61713	83625	0	0	0	0	0
7 Wheat4	0	0	0	0	0	0	0	12819	11286	6967	28981	1951
8 CoarsCereal1	0	0	0	0	0	0	0	0	0	0	0	0
9 CoarsCereal2	0	9430	0	0	0	10401	0	0	0	0	0	0
10 CoarsCereal3	0	0	14918	21232	0	0	0	0	0	0	0	0
11 CoarsCereal4	4016	0	0	0	49302	0	14680	1870	2354	3462	49095	2701
12 Gram	0	1213	5087	9213	13813	1700	42177	488	0	0	27152	0
13 Pulses	0	4004	29631	63265	62064	20021	98101	6006	0	0	120925	12012
14 Sugarcane1	0	0	0	0	0	0	0	0	0	0	0	0
15 Sugarcane2	0	0	0	0	0	0	0	0	0	0	94837	0
16 Sugarcane3	7181	9510	16304	0	0	0	0	0	8254	0	0	0
17 Sugarcane4	0	0	0	133830	0	4133	3414	1363	0	0	0	0
18 OilSeeds1	0	0	105406	0	0	0	0	0	0	0	0	0
19 OilSeeds2	0	14241	0	0	93460	0	141302	0	0	0	108369	0
20 OilSeeds3	0	0	0	25666	0	0	0	15846	0	0	0	0
21 OilSeeds4	1765	0	0	0	0	3088	0	0	0	0	0	0
22 Coconut	0	0	0	0	0	0	0	1729	0	0	850	0
23 Jute	0	0	0	0	0	2529	0	14363	0	0	52	0
24 Cotton1	26921	21560	0	0	0	0	0	0	0	0	0	0
25 Cotton2	0	0	94623	0	0	0	0	0	0	0	0	0
26 Cotton3	0	0	0	0	9813	0	0	0	0	0	80105	0
27 Cotton4	0	0	0	0	0	0	9915	0	0	0	0	0
28 Tea	0	0	0	0	0	0	0	9312	0	0	0	0
29 Coffee	0	0	0	0	0	0	0	0	0	0	0	0
30 Rubber	0	0	0	0	0	0	0	0	0	0	0	0
31 Tobacco	0	0	4105	7314	0	805	0	0	0	0	364	0
32 Fruits	11521	2570	56710	43242	4721	36261	26615	27035	7064	14982	106409	3856
33 Vegetables	22779	26005	45467	126573	4921	89408	9389	151649	7197	6837	42534	24293
34 OtherCrops	29272	33419	58428	162657	6323	114896	12066	194881	9249	8786	54660	31218
35 MilkProds	142114	90134	121123	288776	174190	88542	100622	62575	18694	23257	110390	22078
	629006	422853	642831	1545999	517563	589805	589241	741833	64099	64291	878524	142855

Table 3 continues …

Table 3 continued …

Land type (τ) / *Agricultual activity (k)*	13 HimachalPrad	14 Assam	15 Karnataka	16 AndhraPrad	17 TamilNadu	18 Odisha	19 Chhattisgarh	20 Kerala	21 Goa	22 Meghalaya	23 Others	Total
1 Paddy1	0	8425	64676	243556	105668	120298	71344	9623	0	0	0	1513310
2 Paddy2	0	28987	7357	0	2246	42917	54786	1372	0	0	0	316157
3 Paddy3	0	17269	1928	2284	635	14670	8595	417	0	0	0	100245
4 Wheat1	0	0	0	0	0	0	0	0	0	0	0	360615
5 Wheat2	0	0	0	0	0	0	0	0	0	0	0	509232
6 Wheat3	0	0	0	0	0	0	0	0	0	0	0	145339
7 Wheat4	6967	975	3623	0	0	0	0	0	0	0	2926	76494
8 CoarsCereal1	6244	0	0	29623	0	0	0	0	0	0	0	35867
9 CoarsCereal2	0	0	48122	0	9430	0	0	0	0	0	0	77383
10 CoarsCereal3	0	0	0	0	0	0	0	0	0	0	0	36150
11 CoarsCereal4	0	0	0	0	0	1454	1593	0	0	0	2493	133019
12 Gram	0	0	8962	22064	0	725	5087	0	0	0	1700	139383
13 Pulses	0	0	50852	68070	7608	15216	21622	0	0	0	11612	591009
14 Sugarcane1	0	0	0	0	40873	0	0	0	0	0	0	40873
15 Sugarcane2	0	0	28138	21768	0	0	0	0	0	0	0	144743
16 Sugarcane3	0	0	0	0	0	0	0	0	0	0	0	41248
17 Sugarcane4	0	1052	0	0	0	1181	0	0	0	0	3145	148118
18 OilSeeds1	0	0	0	0	25627	0	0	0	0	0	0	131033
19 OilSeeds2	0	0	0	75435	0	0	0	0	0	0	0	432807
20 OilSeeds3	0	0	34593	0	0	0	0	0	0	0	0	76105
21 OilSeeds4	0	3088	0	0	0	4412	0	0	0	0	10147	22501
22 Coconut	0	660	7939	5433	24122	1340	0	27390	621	0	1505	71589
23 Jute	0	1179	0	866	0	260	0	0	0	87	87	19424
24 Cotton1	0	0	0	0	0	0	0	0	0	0	0	48481
25 Cotton2	0	0	0	39883	0	0	0	0	0	0	0	134506
26 Cotton3	0	0	8901	0	2282	0	0	0	0	0	0	101101
27 Cotton4	0	0	0	0	0	0	0	0	0	0	1614	11529
28 Tea	169	19838	202	0	5668	0	0	2024	0	0	371	37585
29 Coffee	0	6	16301	212	2072	212	0	8603	0	6	29	27440
30 Rubber	0	0	1571	0	2469	0	0	66767	0	0	0	70807
31 Tobacco	0	0	2391	9092	472	0	0	0	0	0	1084	25627
32 Fruits	6084	15338	51328	111106	4648	14930	9318	24924	858	2871	84472	666864
33 Vegetables	8442	19481	51597	35183	58066	56556	20312	23441	385	2777	28851	862144
34 OtherCrops	10849	25035	66306	45213	74620	72680	26103	30123	494	3569	37076	1107927
35 MilkProds	15418	11514	64979	136648	100132	24880	13259	34495	888	1179	6660	1652549
	54172	152849	519765	846438	466639	371730	232019	229179	3247	10490	193775	9909204

enhance the treatment of agricultural land in NCAER-VU. Table 3 shows output by agricultural industry in 23 regions.[15] Our approach is to use these data to disaggregate the land row in Figure 1. We assume for the Paddy1 industry that: 10.89 per cent [=100*164861/1513310] of the agricultural land rents accrue to agricultural land in Punjab; 4.53 per cent [=100*68492/1513310] accrue to agricultural land in Haryana; etc. This allows us to disaggregate LAND(Paddy1) into 23 parts. We apply a similar approach to each of the industries listed in Table 3. For example, we assume for Gram that: none of LAND(Gram) accrues to Punjab land; 0.87 per cent [=100*1213/139383] accrues to Haryana land; etc. Having completed this process we have a 23 by 35 matrix showing agricultural land rents by region and agricultural activity. The transpose of this 23 by 35 matrix is given in Table 4. Looking across a row of the 23 by 35 agricultural-land rental matrix (column in Table 4) we can see how each agricultural activity competes for land in each region. For example, Paddy 1 uses 19.53 per cent of Punjab agricultural land (= 100*36235/185537), Wheat1 uses 33.79 per cent of Punjab agricultural land (= 100*62702/185537), etc. We should point out that we are measuring agricultural land in rental units, not necessarily area. If we think of Punjab agricultural land as being 100 rental units, then 19.53 of these units are used by Paddy1, 33.79 of these units are used by Wheat1, etc.

With the 23 by 35 matrix of agricultural land rents in place, we can equip NCAER-VU with the ability to project rental rates and quantities for land in each region and for each activity according to a demand and supply specification. On the demand side, agricultural industries choose their inputs of each type of land to minimize rental costs subject to a CES land requirement function. In percentage change terms this leads to input demand equations of the form

$$\mathrm{xaland}(\tau, j) = \mathrm{xaland\_ind}(j) - \sigma_{\mathrm{aland}}(j) * \left(\mathrm{paland}(\tau, j) - \sum_{r} \mathrm{Saland}(r, j) * \mathrm{paland}(r, j) \right) \quad (9)$$

$$+ \quad \text{technical change terms}$$

for τ = 1, 2, …, 23 and j= 1, 2, …, 35.

where

xaland(τ,j) is the percentage change in the demand by agricultural industry j (e.g. Paddy1, Gram, etc) for agricultural land of type τ (e.g. Punjab land, Haryana land, etc);

xaland_ind(j) is the percentage change in the overall land requirement by agricultural industry j and is determined in equations such as (3) taking account of the demand for the product of industry j, and the overall price of agricultural land to industry j relative to the prices of substitutable inputs including capital and labour;

paland(τ,j) is the percentage change in the rental price to agricultural industry j of agricultural land of type τ;

$\sigma_{\mathrm{aland}}(j)$ is the elasticity of substitution between land types from the point of view of industry j, and is a positive parameter (currently set at 2) whose value must be set by judgment in light of simulation results; and

Saland(r,j) is the r,jth column share in our 23 by 35 matrix of land rents, and is the share of land-type r in the rental value of agricultural land used by industry j.

[15] The output totals for the industries in this table include diagonal flows. This explains why they differ from the values in column (1) of Table 2.

Table 4. Land rents by agricultural industry and land type (region)

Land type (τ) / *Agricultual activity (k)*	1 Punjab	2 Haryana	3 Gujarat	4 UttarPradesh	5 Rajasthan	6 Bihar	7 MadhyaPrad	8 WestBengal	9 Uttarakhand	10 JamKashmir	11 Maharashtra	12 Jharkhand
1 Paddy1	36235	15054	6637	61507	0	26640	3453	38629	0	0	6107	1291
2 Paddy2	0	6	1625	3730	0	4782	5932	10586	0	0	4416	7786
3 Paddy3	45	0	0	2241	0	2845	948	3795	0	0	1242	674
4 Wheat1	62702	40844	0	0	0	0	0	0	0	0	0	0
5 Wheat2	0	0	15137	101229	28067	0	0	0	0	0	0	0
6 Wheat3	0	0	0	0	0	17529	23753	0	0	0	0	0
7 Wheat4	0	0	0	0	0	0	0	3707	3264	2015	8382	564
8 CoarsCereal1	0	0	0	0	0	0	0	0	0	0	0	0
9 CoarsCereal2	0	2697	0	0	0	2974	0	0	0	0	0	0
10 CoarsCereal3	0	0	4127	5874	0	0	0	0	0	0	0	0
11 CoarsCereal4	1136	0	0	0	13950	0	4154	529	666	980	13892	764
12 Gram	0	391	1640	2971	4454	548	13599	157	0	0	8755	0
13 Pulses	0	953	7051	15055	14769	4764	23345	1429	0	0	28776	2859
14 Sugarcane1	0	0	0	0	0	0	0	0	0	0	0	0
15 Sugarcane2	0	0	0	0	0	0	0	0	0	0	35629	0
16 Sugarcane3	2822	3737	6407	0	0	0	0	0	3243	0	0	0
17 Sugarcane4	0	0	0	51283	0	1584	1308	522	0	0	0	0
18 OilSeeds1	0	0	33372	0	0	0	0	0	0	0	0	0
19 OilSeeds2	0	4481	0	0	29408	0	44462	0	0	0	34099	0
20 OilSeeds3	0	0	0	7962	0	0	0	4916	0	0	0	0
21 OilSeeds4	570	0	0	0	0	998	0	0	0	0	0	0
22 Coconut	0	0	0	0	0	0	0	527	0	0	259	0
23 Jute	0	0	0	0	0	842	0	4781	0	0	17	0
24 Cotton1	8896	7124	0	0	0	0	0	0	0	0	0	0
25 Cotton2	0	0	30670	0	0	0	0	0	0	0	0	0
26 Cotton3	0	0	0	0	3146	0	0	0	0	0	25683	0
27 Cotton4	0	0	0	0	0	0	3024	0	0	0	0	0
28 Tea	0	0	0	0	0	0	0	3463	0	0	0	0
29 Coffee	0	0	0	0	0	0	0	0	0	0	0	0
30 Rubber	0	0	0	0	0	0	0	0	0	0	0	0
31 Tobacco	0	0	1601	2852	0	314	0	0	0	0	142	0
32 Fruits	4782	1067	23540	17949	1959	15051	11048	11222	2932	6219	44169	1601
33 Vegetables	9413	10746	18788	52304	2033	36946	3880	62666	2974	2825	17576	10039
34 OtherCrops	9289	10604	18540	51614	2007	36459	3829	61839	2935	2788	17344	9906
35 MilkProds	49647	31488	42314	100883	60853	30932	35152	21860	6531	8125	38565	7713
	185537	129193	211449	477454	160646	183209	177887	230629	22546	22951	285053	43196

Table 4 continues …

Table 4 continues …

Land type (τ) / ***Agricultual activity (k)***	13 HimachalPrad	14 Assam	15 Karnataka	16 AndhraPrad	17 TamilNadu	18 Odisha	19 Chhattisgarh	20 Kerala	21 Goa	22 Meghalaya	23 Others	Total
1 Paddy1	0	1852	14215	53531	23225	26441	15681	2115	0	0	0	332613
2 Paddy2	0	6311	1602	0	489	9344	11928	299	0	0	0	68836
3 Paddy3	0	3740	417	495	138	3177	1861	90	0	0	0	21708
4 Wheat1	0	0	0	0	0	0	0	0	0	0	0	103546
5 Wheat2	0	0	0	0	0	0	0	0	0	0	0	144433
6 Wheat3	0	0	0	0	0	0	0	0	0	0	0	41282
7 Wheat4	2015	282	1048	0	0	0	0	0	0	0	846	22122
8 CoarsCereal1	1744	0	0	8272	0	0	0	0	0	0	0	10016
9 CoarsCereal2	0	0	13761	0	2697	0	0	0	0	0	0	22129
10 CoarsCereal3	0	0	0	0	0	0	0	0	0	0	0	10000
11 CoarsCereal4	0	0	0	0	0	411	451	0	0	0	705	37639
12 Gram	0	0	2890	7114	0	234	1640	0	0	0	548	44942
13 Pulses	0	0	12101	16198	1810	3621	5145	0	0	0	2763	140641
14 Sugarcane1	0	0	0	0	15146	0	0	0	0	0	0	15146
15 Sugarcane2	0	0	10571	8178	0	0	0	0	0	0	0	54379
16 Sugarcane3	0	0	0	0	0	0	0	0	0	0	0	16209
17 Sugarcane4	0	403	0	0	0	452	0	0	0	0	1205	56758
18 OilSeeds1	0	0	0	0	8114	0	0	0	0	0	0	41485
19 OilSeeds2	0	0	0	23736	0	0	0	0	0	0	0	136186
20 OilSeeds3	0	0	10732	0	0	0	0	0	0	0	0	23610
21 OilSeeds4	0	998	0	0	0	1426	0	0	0	0	3279	7270
22 Coconut	0	201	2419	1656	7351	408	0	8347	189	0	459	21816
23 Jute	0	392	0	288	0	87	0	0	0	29	29	6465
24 Cotton1	0	0	0	0	0	0	0	0	0	0	0	16020
25 Cotton2	0	0	0	12927	0	0	0	0	0	0	0	43598
26 Cotton3	0	0	2854	0	732	0	0	0	0	0	0	32415
27 Cotton4	0	0	0	0	0	0	0	0	0	0	492	3517
28 Tea	63	7377	75	0	2108	0	0	753	0	0	138	13976
29 Coffee	0	2	4551	59	579	59	0	2402	0	2	8	7662
30 Rubber	0	0	608	0	955	0	0	25834	0	0	0	27397
31 Tobacco	0	0	932	3545	184	0	0	0	0	0	423	9992
32 Fruits	2526	6367	21306	46119	1929	6197	3868	10346	356	1192	35063	276808
33 Vegetables	3489	8050	21321	14539	23995	23371	8394	9686	159	1148	11922	356265
34 OtherCrops	3443	7944	21040	14347	23678	23063	8283	9559	157	1132	11765	351565
35 MilkProds	5386	4022	22700	47738	34981	8692	4632	12051	310	412	2327	577315
	18664	47942	165145	258743	148109	106982	61883	81481	1172	3915	71973	3095759

On the supply side, holders of agricultural land in each region choose the industries to which they will rent out their land by maximizing a welfare function subject to a land constraint. In percentage change terms this leads to agricultural land supply equations of the form

$$\mathrm{xaland}(\tau, j) = \mathrm{xaland\_type}(\tau) + \psi_{\mathrm{aland}}(\tau) * \left(\mathrm{paland}(\tau, j) - \sum_{k} \mathrm{Raland}(\tau, k) * \mathrm{paland}(\tau, k) \right) \quad (10)$$

$$+ \quad \text{technical change terms}$$

for τ = 1, 2, …, 23 and j= 1, 2, …, 35.

where

xaland_type(τ) is the percentage change (usually set exogenously at zero) in the overall availability of agricultural land of type τ;

$\psi_{\mathrm{aland}}(\tau)$ is the elasticity of substitution between agricultural activities from the point of view of the owner of land type τ and is a positive parameter (currently set at 2) whose value must be set by judgment in light of simulation results; and

Raland(τ,k) is the (τ,k)th row share in our 23 by 35 matrix of land rents, and is the share of land of type τ devoted to crop k.

With xaland_type(τ) set exogenously, the inclusion of (9) and (10) in NCAER-VU provide 2x23x35 equations to determine the same number of variables, xaland(τ,j) and paland(τ,j).

The data in Figure 1 contain non-zero entries in the LAND vector for mining industries. We refer to these entries as non-agricultural land rents. In NCAER-VU, non-agricultural land can be treated in several ways including: industry specific with exogenous quantities and endogenous rental rates; and industry-specific with endogenous quantities and exogenous rental rates.

3. Illustrative simulation: removing agricultural subsidies

In this section we discuss NCAER-VU simulations of the effects of removing agricultural subsidies. Agricultural subsidies are not only a major political and economic issue in India, but analysis of their effects is an excellent topic for demonstrating the workings of a CGE model. For other recent applications of CGE models to analysis of agricultural policies in developing countries see Giesecke *et al.* (2013), Mariano and Giesecke (2014) and Mariano *et al.* (2014).

We present four simulations which can be described as follows:

1) Remove subsidies on Fertilizer inputs to agricultural industries, holding rates of all other subsidies constant. In the 2007-8 database the agricultural Fertilizer subsidies total Rs 213,428m [Table 2, column (5)] or 0.428 per cent of GDP. The average rate of Fertilizer subsidy to agricultural industries is 47.7 per cent [Table 2, column (6)].
2) Remove subsidies on Electricity inputs to agricultural industries, holding rates of all other subsidies constant. In the 2007-8 database the agricultural Electricity subsidies total Rs 172,646m [Table 2, column (9)] or 0.346 per cent of GDP. The average rate of Electricity subsidy to agricultural industries is 62.6 per cent [Table 2, column (10)].
3) Remove subsidies on both Fertilizer and Electricity inputs to agricultural industries, holding rates of all other subsidies constant. This is a combination of 1) and 2) above.

4) Same as 3) plus remove production subsidies on agricultural industries and subsidies on intermediate and consumption sales of agricultural commodities. As explained in subsections 2.4(a) & (b), the production subsidies in the NCAER-VU database were initially subsidies on diagonal sales. They became production subsidies when we eliminated the diagonal sales. In the 2007-8 database, production subsidies for agricultural industries formed in this way total Rs 131,520m [Table 2, column (11)] or 0.264 per cent of GDP. The average production subsidy rate (subsidy/all-input-costs) over agricultural industries is 1.5 per cent [Table 2, column (12)]. The subsidies on intermediate and consumption sales of agricultural commodities total Rs 738,587m [Table 2, column (13)] or 1.481 per cent of GDP. The average rate of sales subsidy is 8.4 per cent [Table 2, column (14)]. In total, the extra subsidies removed in simulation 4) relative to simulation 3) are worth Rs 870,107m (1.745 per cent of GDP). The total for all subsidies removed in simulation 4) is Rs 1,256,181m [Table 2, column (15)] or 2.519 per cent of GDP.

3.1. Macroeconomic results

Assumptions

Results for macroeconomic variables from the four simulations are given in Table 5. The first five rows are entirely filled with zeros. They are included in the table to make our main macroeconomic assumptions explicit. We assume that the removal of subsidies has no effect on aggregate employment, aggregate capital and land, technology[16], the balance of trade and the nominal exchange rate. The first three of these assumptions mean that our simulations are focused on efficiency effects of subsidy removal, that is the benefits of reallocating a given quantity of resources (labour, capital and land) with given technologies away from subsidized uses in which marginal benefits are less than in alternative unsubsidized uses. The fourth assumption means that the economy uses the efficiency benefit (the increase in GDP) as extra absorption (an increase in C+I+G), leaving no change in the balance of trade. The fifth assumption determines the price level. It has no implications for real variables such as the effects on real GDP. In the jargon of CGE modelling, we have chosen the exchange rates as the numeraire. Adjustments in the real exchange rate (competitiveness) necessary to ensure zero outcomes for the change in the balance of trade take place via changes in the domestic price level, indicated by movements in the price deflator for GDP (row 13, Table 5).

Simulations 1) to 3)

The first two simulations (removal of subsidies on Fertilizer inputs to agriculture and removal of subsidies on Electricity inputs to agriculture) show GDP gains of 0.060 and 0.089 per cent (row 6 in Table 5). These results can be explained in terms of consumer and producer surplus diagrams, see Figures 3 and 4. In these figures, we measure quantity as the amount that had a basic value of Rs 1m in the initial situation. Figure 3 shows the basic price of Fertilizer in the initial situation as 1 and the quantity purchased as 447,400 units, corresponding to the basic value in our database of Fertilizer purchases by farmers of Rs 447,400m, which is 0.897% of GDP. The purchasers' value is 52.3 per cent of the basic value, reflecting the average subsidy rate of 47.7 per cent. Removal of the fertilizer subsidy increases the price of Fertilizer to farmers from 0.523 to 1. The simulated effect on their

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[16] By technology we mean A variables in production functions of the form $Y_j = F_j\left(\frac{X_{1j}}{A_{1j}}, \frac{X_{2j}}{A_{2j}}, ..., \frac{X_{nj}}{A_{nj}}\right)$ where Y_j and X_{ij} are output and inputs for industry j.

Table 5. Percentage effects on Macro variables of removing agricultural subsidies on: Fertilizer, Electricity, production and sales

	Simulation	Fertilizer (1)	Electricity (2)	Fertilizer & Electricity (3)	Fertilizer, Electricity, production & sales (4)
1	Aggregate employment	0.000	0.000	0.000	0.000
2	Aggregate capital & land	0.000	0.000	0.000	0.000
3	Technology	0.000	0.000	0.000	0.000
4	Balance of trade *(change)*	0.000	0.000	0.000	0.000
5	Nominal exchange rate	0.000	0.000	0.000	0.000
6	Real GDP	0.060	0.089	0.156	0.204
7	Real private consumption	0.097	0.100	0.202	0.241
8	Real aggregate investment	0.097	0.100	0.202	0.241
9	Real public consumption	0.097	0.100	0.202	0.241
10	Real aggregate exports	-0.690	-0.081	-0.768	-0.788
11	Real aggregate imports	-0.415	-0.022	-0.436	-0.492
12	Terms of trade	0.186	0.053	0.240	0.192
13	Price deflator for GDP	0.460	0.241	0.705	1.710

demand for Fertilizer is a reduction of 26.86 per cent. As shown in Figure 3, this suggests a GDP gain of Rs 28,663m or 0.057 per cent of GDP. For removal of the subsidy on Electricity inputs to agriculture, Figure 4 suggests a GDP gain of Rs 32,924m or 0.066 per cent of GDP.

The back-of-the-envelope calculations in Figures 3 and 4 understate the simulated gains shown in Table 5: a back-of-the-envelope gain of 0.057 per cent compared with a simulated gain of 0.060 per cent in the Fertilizer simulation; and a back-of-the-envelope gain of 0.066 per cent compared with a simulated gain of 0.089 per cent in the Electricity simulation. The principal reason is that the demand curves implied by NCAER-VU are concave from above rather than linear, meaning that the GDP triangles in Figures 3 and 4 underestimate the gains from reducing the use of subsidized Fertilizer and Electricity. NCAER-VU also captures gains and losses from induced changes in taxed/subsidized flows apart from the directly affected Fertilizer and Electricity flows to agriculture. Detailed inspection of our results indicates that these secondary effects are more favourable in simulation 2), the Electricity simulation, than in simulation 1), the Fertilizer simulation. Reductions in the use of fertilizer reduce imports of Fertilizer which bear a tariff. At the same time, a reduction in imports causes a general reduction in exports (recall that we assume zero effect on the balance of trade) which bear export taxes. By contrast, reductions in the use of electricity have relatively little impact on tax-bearing trade flows. These trade effects can be seen in rows 10 and 11 of Table 5. In simulation 1), aggregate export and import volumes fall by 0.690 and 0.415 per cent whereas in simulation 2) aggregate export and import volumes fall by only 0.081 and 0.022 per cent.

In simulation 1) it is clear why trade contracts: as we have already explained, the main reason is the contraction in Fertilizer imports. But there is a secondary reason, which applies

Figure 3. Removing the subsidy on Fertilizer inputs to Agriculture: calculating the GDP or welfare triangle

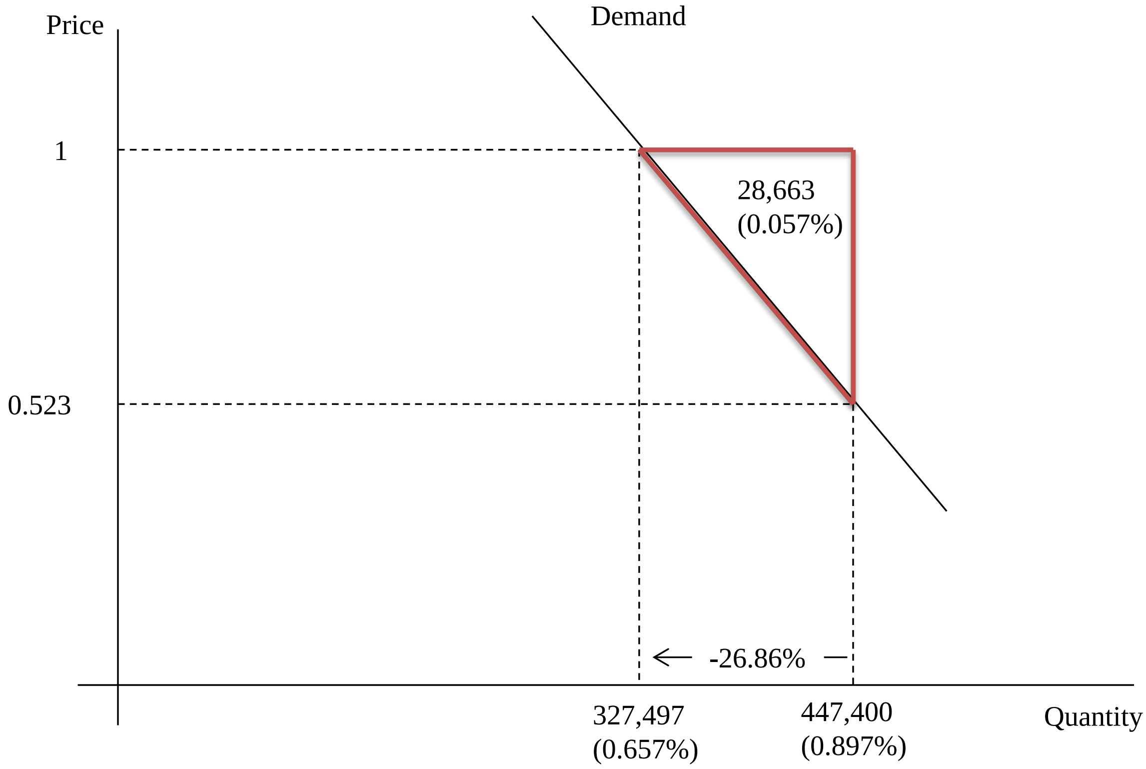
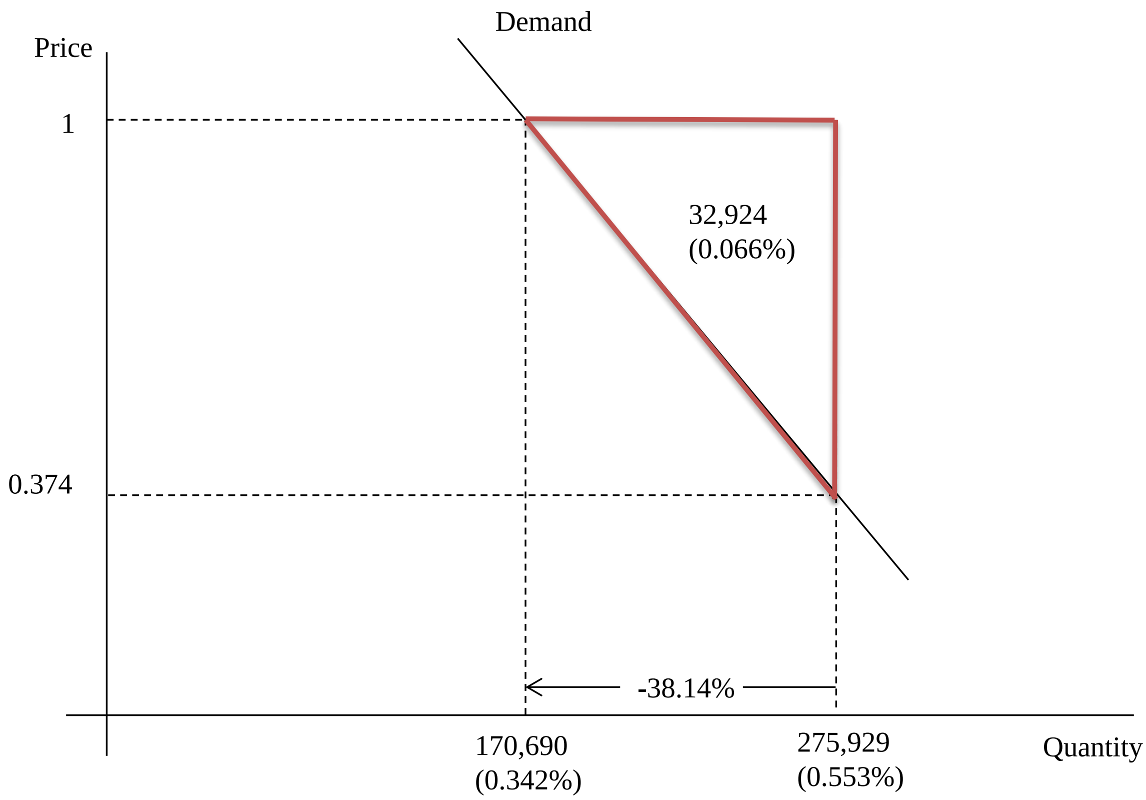


Figure 4. Removing the subsidy on Electricity inputs to Agriculture: calculating the GDP or welfare triangle



to simulation 2) as well as simulation 1). Removal of subsidies increases the prices of agricultural and agriculture-intensive exports thereby reducing foreign demands. Then, under our assumption of balanced trade, there is a corresponding reduction in imports.

Results for aggregate private consumption, investment and public consumption are given in rows 7 to 9 of Table 5. In each column, percentage movements in these variables are the same: we assume that subsidy removal does not affect the broad composition of gross national expenditure (C+I+G). Under our assumption of fixed balance of trade, the percentage movement in gross national expenditure (GNE) is an indicator of welfare. For the Fertilizer and Electricity simulations, the welfare effects (0.097 per cent and 0.100 per cent) measured in this way exceed those in GDP (0.060 and 0.089 per cent).

The source of the extra GNE increases beyond those in GDP is the terms of trade. In NCAER-VU, India faces downward-sloping foreign demand curves for exports but flat supply curves for imports. Consequently, trade contractions in simulations 1) and 2) generate terms-of-trade improvements (row 12, Table 5). This explains why the percentage reductions in exports are greater than in imports, even though we assume zero change in the balance of trade. It also explains why in both simulations 1) and 2) the percentage expansions in GNE exceed those in GDP.[17] The deteriorations in the real trade balances (and the consequent increases in real GNE relative to real GDP) are facilitated in NCAER-VU by real appreciation (increases in the price deflator for GDP, row 13).

The results in Table 7 for simulation 3), in which both the Fertilizer and Electricity subsidies are removed, show GDP and GNE effects that are greater than the sum of the effects in simulations 1) and 2). For example, the GDP effects in simulations 1) and 2) sum to 0.149 per cent, whereas the GDP effect in simulation 3) is 0.156 per cent. Removal of the subsidy on Fertilizer [simulation 1)] introduces a distortion in the choice by farmers between subsidized Electricity inputs and the now unsubsidized Fertilizer inputs. This acts as a small offset to the gains associated with the elimination of the distortion in the choice between Fertilizer and other inputs excluding Electricity. Similarly, removal of the subsidy on Electricity [simulation 2)] introduces a distortion in the choice by farmers between subsidized Fertilizer inputs and the now unsubsidized Electricity inputs. This acts as a small offset to the gains associated with the elimination of the distortion in the choice between Electricity and other inputs excluding Fertilizer. When the Fertilizer and Electricity subsidies are removed together, then the Fertilizer/Electricity choice is not distorted, generating gains from joint removal that are greater than the sum of the gains in the two individual removals. However, from a practical point of view, simulation 3) is close to the sum of simulations 1) and 2): the interaction effects are quantitatively small.

Simulation 4)

As can be seen from the descriptions of the simulations at the beginning of this section, the Fertilizer and Electricity subsidies removed in simulation 3) are worth 0.774 per cent of GDP (0.428 plus 0.346). In simulation 4), there is additional removal of subsidies worth more than twice as much, 1.745 per cent of GDP. Nevertheless, simulation 4) shows relatively small GDP and GNE benefits beyond those in simulation 3): 0.204 per cent compared with 0.156

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[17] In change form we can write the GDP identity as: $Y*y = B*b + X*x - M*m$ leading to $b = \frac{Y}{B}*y - \frac{X}{B}*x + \frac{M}{B}*m$, where y, b, x and m are percentage changes in real GDP, real GNE, real exports and real imports, and Y, B, X and M are corresponding initial values. With trade broadly balanced we can approximate the percentage movement in GNE by: $b = y + \frac{X}{B}*(m - x)$. With m-x greater than zero, b is greater than y.

per cent for GDP; and 0.241 per cent compared with 0.202 per cent for GNE. The relatively small gain from removing production and sales subsidies on agricultural products reflects low demand and supply elasticities and subsidy rates.

From columns (11) and (13) in Table 2 we can see that production and sales subsidies are applied predominantly on Paddy, Wheat, Sugar cane, Cotton and Other crops. Figure 5 represents the demand and supply curves for these highly subsidized crops. It shows the initial quantity of output as 3,954,739m units, calculated from the values in column (1) of Table 2 under the assumption that a unit is the quantity that had a basic price in 2007-8 of one. The production and sales subsidies cause purchasers prices to be 0.790 times the basic price [a subsidy rate of 21.0 per cent calculated as 100*831946/3954739]. Our simulation results for commodity outputs (shown below in Table 6), imply that removal of production and sales subsidies reduces output of the highly subsidized commodities by 3.24 per cent. Via Figure 5, this suggests a GDP gain of Rs 13,454m or 0.027 per cent.

The simulated GDP gain is 0.048 per cent (= 0.204 – 0.156, row 6, Table 5). We traced the extra 0.021 per cent gain (the difference between 0.048 and 0.027) to induced movements in tax/subsidy-carrying flows apart from the directly affected sales and output of agricultural commodities. For example, removal of production and sales subsidies on agricultural commodities changes the composition of Indian exports away from agriculture-intensive commodities such as Apparel, Miscellaneous textile products, Cotton textiles, Miscellaneous food products and Leather products towards non-agricultural manufactured products and services such as Motor vehicles, Communications, Petroleum products, Business services and Other services. Our database shows high export taxes for this latter group relative to those for the former group.

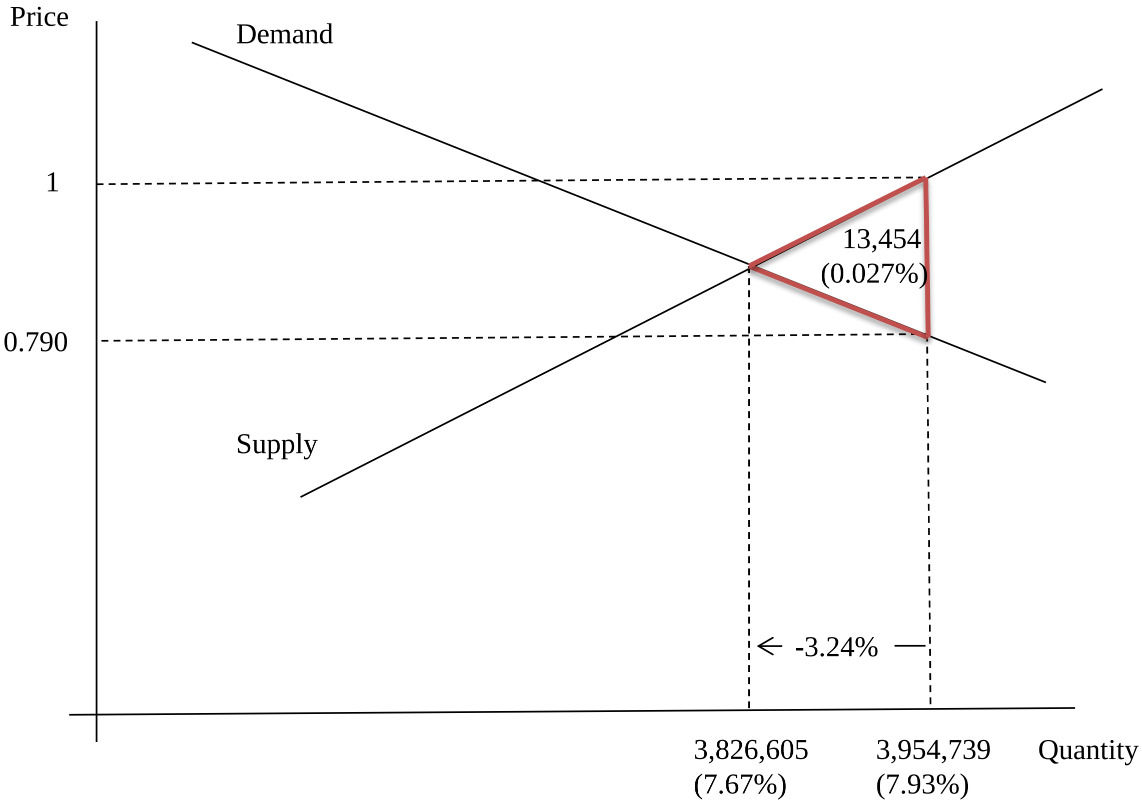
While the removal of agricultural production and sales subsidies increases real GDP by 0.048 per cent, the increase in real GNE is only 0.039 per cent (= 0.241 - 0.202, Table 5, rows 7-9). The reason for the subdued response of GNE is that the terms-of-trade improvement is reduced in simulation 4) relative to simulation 3) [0.192 per cent in simulation 4), down from 0.240 per cent in simulation 3)]. At first glance, the lower terms-of-trade improvement in simulation 4) relative to 3) seems surprising in view of the greater contraction in exports in 4) than in 3) [0.788 per cent compared with 0.768 per cent]. The explanation is found in the export demand elasticities adopted in NCAER-VU. The agriculture-intensive exports that contract when production and sales subsidies are removed have higher export demand elasticities than the non-agricultural exports that expand.

Efficiency of input subsidies versus production and sales subsidies

Table 5 and our discussion of simulations 3) and 4) give the strong impression that subsidies on Fertilizer and Electricity inputs are a relatively inefficient way of supporting producers and consumers of agriculture commodities (the agricultural sector). The Electricity and Fertilizer subsidies provide the agricultural sector with support worth Rs 386,074m, but cost the economy 0.156 per cent of GDP [simulation 3, row 6, Table 5]. The agricultural production and sales subsidies provide the agricultural sector with a much greater level of support, Rs 870,107m, but cause a smaller reduction, 0.048 per cent, in GDP (0.204 -0.156, row 6, Table 5).

The split of the GDP effect of removing all agricultural subsidies (0.204 per cent) into the part attributable to input subsidies (0.156 per cent) and the part attributable to production and sales subsidies (0.048 per cent) depends on the ordering of our simulations. The split is different if we remove the production and sales subsidies first and the input subsidies second.

Figure 5. Removing subsidies on production and sales of agricultural commodities: calculating the GDP or welfare triangle



The reason is that in a simulation in which production and sales subsidies are removed first, there is a GDP benefit from the induced contraction in subsidized Fertilizer and Electricity inputs to agriculture caused by the contraction in agriculture. When the production and sales subsidies are removed second [as was done in simulation 4)], there is no extra benefit in reducing Fertilizer and Electricity inputs because they are no longer subsidized.

To test the quantitative importance of this idea, we conducted a simulation in which the production and sales subsidies where eliminated first. In this case, the split of the total GDP effect (0.204 per cent) was 0.134 per cent for input subsidies and 0.070 per cent for production and sales subsidies, still strongly pointing to the conclusion that input subsidies are a costly way of providing support to the producers and consumers of agricultural products.

For understanding this conclusion, it is useful to think in terms of a sequence. First, we can think of providing support to the agricultural sector of Rs 1,256,181m [the total of all agricultural subsidies shown in column (15) of Table 2]. As illustrated in Figure 6, it is not important whether the subsidies are on sales or production. In either case, the GDP loss is confined to the welfare triangle. Next, we can think of some of the support being converted into input subsidies. This doesn't affect the total amount of support. Consequently it doesn't affect the welfare triangle in Figure 6. However, it generates an additional distortion: a distortion in the choice by farmers of their input mix. The extent of this additional distortion depends on the substitution elasticity between inputs. If the substitution elasticity is zero, then the additional distortion has zero GDP or welfare effect.[18] In the case of Fertilizers and

[18] This can be demonstrated in simulations which show that input and output subsidies have the same effects if there is zero substitution between the subsidized inputs and other inputs.

Electricity, zero does not reflect the possibilities for using these inputs as substitutes for animal power, labour, capital, land, etc. In our simulations we used a substitution elasticity of 0.5 which, in the context of NCAER-VU, implied demand elasticities of about 0.5 by farmers for Fertilizer and Electricity (see Figures 3 and 4). With these seemingly moderate demand elasticities, GDP losses associated with additional input distortions can be large. For India, only 31 per cent of total agricultural support (Rs 386,074m out of Rs 1,256,181m) is provided by input subsidies. Yet we find that about 71 per cent of the GDP cost of support is attributable to these input subsidies. [19]

3.2. Industry results

The effects on industry and commodity variables of removing agricultural subsidies are given in Tables 6 to 8. We divide our discussion of these tables into three parts. The first two are concerned with agriculture and food. The third part is a brief discussion of results for non-agricultural industries.

3.2(a). Outputs of agricultural commodities/industries, 1 to 41

Column (4) of Table 6 shows a wide range of results for the outputs of agricultural industries, from -14.98 for Cotton4 to 4.54 for Oilseeds4. The output-weighted average over all agricultural industries (excluding the 6 artificial mixing industries) is a contraction of 2.30 per cent.

A useful technique for explaining industry results from a CGE model is regression analysis. We develop hypotheses about features of the model and shocks (in this case subsidy removal) that we think are likely to explain the results. Then we test the hypotheses by regression equations in which CGE results appear on the left hand side. On the right hand side we can include data and parameter values from the model as well as exogenous shocks. Of course, we should not include on the right hand side endogenous outcomes from the model. If we did, then we would be in danger of circularity: explaining result *x* by result *y*, but what explains result *y*.

The most obvious explanator of the effects on the outputs of agricultural industries of removing agricultural subsidies is the initial rate of the subsidies. We expect industries with initially high subsidy rates to show negative results in column (4) of Table 6 relative to industries with initially moderate subsidy rates. We tested this idea by regressing the output results for 35 agricultural industries (we exclude the 6 mixing industries) against the subsidy rates in column (16) of Table 2. The result is:

$$\underset{(0.87)}{Y(i) = -0.164} \;\; \underset{(0.04)}{- 0.170*SR(i)} \qquad R^2 = 0.36 \tag{11}$$

where

Y(i) is the percentage change in the output of agricultural industry i [column (4), Table 6];
SR(i) is the initial subsidy rate for agricultural industry i [column (16), Table 2]; and
the numbers in brackets are standard errors.

While the coefficient on SR in equation (11) has the expected negative sign, the R-squared of only 0.36 suggests that there must be other factors operating in NCAER-VU that

[19] As mentioned earlier in this subsection, we have two estimates of the GDP loss associated with input subsidies depending on the ordering of the subsidy removals. The average of these two estimates is 0.145 per cent of GDP [=(0.156 +0.134)/2]. This is 71 per cent of the total GDP loss associated with agricultural subsidies [71 = 100*(0.145/0.204)].

Table 6. Percentage effects on commodity outputs of removing agricultural subsidies on: Fertilizer, Electricity, production and sales

	Commodity	Fertilizer (1)	Electricity (2)	Fertilizer & Electricity (3)	Fertilizer, Electricity, production & sales (4)
1	Paddy	-0.49	-0.50	-0.96	-3.09
2	Paddy1	0.08	-0.51	-0.41	-2.55
3	Paddy2	-1.92	-0.52	-2.37	-4.53
4	Paddy3	-4.48	-0.32	-4.69	-6.65
5	Wheat	-0.91	-0.84	-1.78	-6.26
6	Wheat1	-1.13	-1.50	-2.63	-6.75
7	Wheat2	-1.16	-0.53	-1.73	-6.26
8	Wheat3	-2.55	-1.27	-3.79	-8.60
9	Wheat4	4.92	1.07	5.83	0.51
10	CoarsCereal	-0.51	-0.24	-0.73	-1.23
11	CoarsCereal1	-3.13	-0.34	-3.41	-4.06
12	CoarsCereal2	1.00	-0.69	0.31	-0.27
13	CoarsCereal3	-4.82	-0.06	-4.80	-4.94
14	CoarsCereal4	0.51	0.00	0.50	-0.02
15	Gram	-0.35	-0.20	-0.54	-2.48
16	Pulses	-0.34	-0.13	-0.46	-0.74
17	Sugarcane	-0.87	-0.46	-1.29	-3.83
18	Sugarcane1	-7.83	0.13	-7.59	-10.56
19	Sugarcane2	-2.99	-0.57	-3.47	-6.33
20	Sugarcane3	5.41	-0.82	4.52	2.40
21	Sugarcane4	1.42	-0.43	1.00	-1.21
22	OilSeeds	-1.28	-0.38	-1.64	-2.76
23	OilSeeds1	0.02	-0.46	-0.44	-1.43
24	OilSeeds2	-1.35	-0.37	-1.71	-2.88
25	OilSeeds3	-5.00	-0.48	-5.41	-6.52
26	OilSeeds4	5.51	0.23	5.69	4.54
27	Coconut	-0.69	-0.16	-0.83	-1.16
28	Jute	-0.48	0.12	-0.36	-1.28
29	Cotton	-1.14	-0.50	-1.61	-5.65
30	Cotton1	2.26	-0.97	1.27	-2.07
31	Cotton2	-0.93	-0.68	-1.58	-5.72
32	Cotton3	-1.87	-0.13	-1.97	-6.20
33	Cotton4	-11.33	0.35	-10.86	-14.98
34	Tea	-0.52	-0.17	-0.68	-1.13
35	Coffee	-0.44	-0.14	-0.58	-0.97
36	Rubber	-1.36	-0.19	-1.56	-1.12
37	Tobacco	-0.66	-0.39	-1.06	-1.48
38	Fruits	-0.42	-0.25	-0.66	-0.58
39	Vegetables	-0.23	-0.14	-0.37	0.03
40	OtherCrops	-0.47	-0.24	-0.71	-3.94
41	MilkProds	-0.10	-0.05	-0.15	0.04
42	AnimServ	0.38	0.39	0.75	-5.96
43	PoultEggs	-0.03	0.00	-0.03	-0.15
44	OthLiveSt	-0.17	0.11	-0.06	-1.53
45	Forestry	0.08	0.11	0.19	0.45
46	Fishing	-0.01	0.03	0.02	0.10
47	Coal	-0.02	-0.43	-0.45	-0.16
48	NatGas	-0.08	0.02	-0.05	0.20
49	CrudeOil	-0.05	0.04	-0.01	0.21

Table 6 continues …

Table 6 continued …

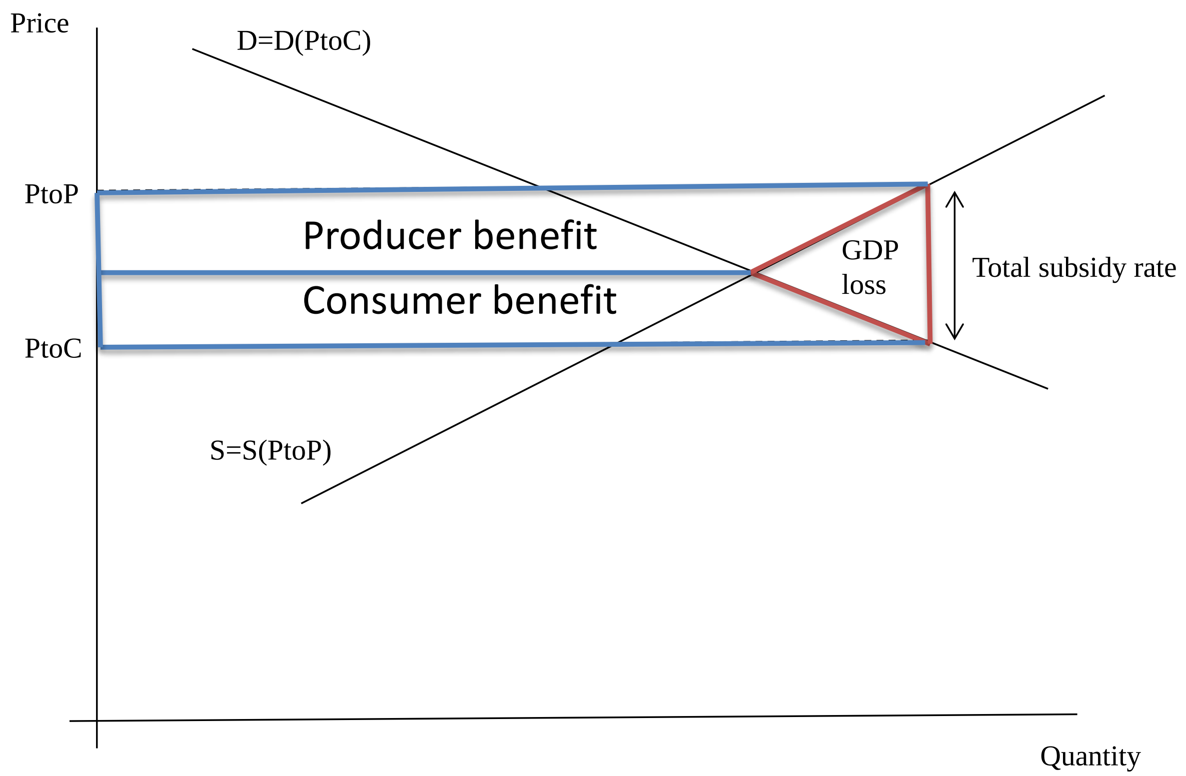
	Commodity	Fertilizer (1)	Electricity (2)	Fertilizer & Electricity (3)	Fertilizer, Electricity, production & sales (4)
50	IronOre	0.03	0.15	0.18	0.70
51	ManganOre	-0.06	0.25	0.20	0.88
52	Bauxite	0.02	0.20	0.22	0.90
53	CopperOre	0.04	0.40	0.44	1.40
54	OthMetMin	0.01	0.13	0.14	0.60
55	Limestone	0.00	0.10	0.10	0.25
56	Mica	0.13	0.65	0.79	2.72
57	OthNonMetMin	-0.03	0.14	0.10	0.65
58	Sugar	-1.41	-0.77	-2.09	-6.09
59	Khandsari	-0.18	-0.06	-0.23	-0.87
60	Vanaspati	-0.25	-0.05	-0.29	-0.52
61	OthEdibleOil	-1.94	-0.60	-2.51	-4.22
62	TeaCoffee	-0.60	-0.19	-0.78	-1.25
63	MiscFoodProd	-0.34	-0.17	-0.51	-1.19
64	Beverages	-0.05	0.02	-0.03	-0.15
65	TobaccoProd	0.03	0.05	0.08	0.15
66	Khadi	-0.81	-0.25	-1.06	-3.66
67	CottonText	-1.22	-0.58	-1.77	-6.19
68	WoolenText	-0.74	-0.23	-0.97	-3.69
69	SilkText	-0.59	-0.06	-0.65	-2.10
70	SynthFibText	-0.56	-0.14	-0.70	-2.53
71	JuteHemp	-0.41	0.19	-0.22	-0.97
72	CarpetWeav	-0.91	0.08	-0.83	-1.05
73	Apparel	-0.76	-0.16	-0.93	-2.97
74	MiscTextProd	-0.44	-0.10	-0.54	-1.99
75	FurnitFixt	0.08	0.06	0.15	0.41
76	WoodProd	-0.04	0.08	0.04	0.14
77	Paperprod	-0.16	-0.01	-0.17	-0.14
78	PrintPub	0.03	0.05	0.08	0.25
79	Footwear	-0.10	0.04	-0.06	-0.54
80	LeathProd	-0.69	-0.10	-0.79	-2.15
81	RubberProd	-0.29	0.07	-0.22	0.06
82	PlasticProd	-0.16	0.10	-0.06	0.08
83	PetrolProd	-0.16	-0.07	-0.24	-0.17
84	CoalProd	0.06	0.07	0.13	0.44
85	InorgChem	-2.58	0.18	-2.42	-2.60
86	OrganChem	-1.05	0.01	-1.05	-1.53
87	Fertilizers	-19.82	0.88	-19.19	-20.68
88	Pesticides	-0.43	0.43	-0.02	-0.84
89	Paints	-0.15	0.09	-0.06	0.07
90	DrugsMedic	-0.34	0.00	-0.34	-0.71
91	SoapsCosmet	0.08	0.15	0.24	0.47
92	SynthFiber	-0.41	0.10	-0.32	-0.39
93	OthChem	-0.53	-0.11	-0.65	-1.06
94	StrClayProd	0.07	0.08	0.16	0.22
95	Cement	0.08	0.08	0.16	0.22
96	OthNMMinProd	0.05	0.14	0.19	0.45
97	IronSteel	0.05	0.25	0.31	0.88
98	ISForge	0.05	0.20	0.25	0.74
99	ISFound	0.06	0.23	0.29	0.78

Table 6 continues …

Table 6 continued …

	Commodity	Fertilizer (1)	Electricity (2)	Fertilizer & Electricity (3)	Fertilizer, Electricity, production & sales (4)
100	NonFerMetals	0.03	0.67	0.71	1.87
101	HandTools	-0.02	0.17	0.16	0.66
102	MiscMetProd	0.06	0.17	0.24	0.64
103	Tractors	0.15	0.19	0.35	0.41
104	IndMachFT	-0.02	0.22	0.20	0.71
105	IndMachOth	-0.06	0.23	0.17	0.85
106	MachineTool	0.02	0.21	0.23	0.86
107	OthNonEleMac	0.01	0.19	0.21	0.95
108	ElecIndMach	0.08	-0.24	-0.16	0.41
109	WiresCables	0.05	0.19	0.24	0.70
110	Batteries	-0.02	0.20	0.18	0.87
111	ElectApp	0.14	0.18	0.33	0.77
112	CommunEquip	0.04	0.32	0.36	1.49
113	OthEleMach	0.00	0.02	0.02	0.93
114	ElectronEqu	0.05	0.26	0.31	1.24
115	Ships	-0.02	0.17	0.15	1.06
116	RailEquip	-0.04	0.03	-0.01	0.30
117	MotorVeh	0.08	0.14	0.22	0.57
118	MotorCycle	0.14	0.17	0.31	0.75
119	Bicycles	0.09	0.14	0.22	0.56
120	OthTranEquip	0.15	0.30	0.46	1.05
121	WatchClock	0.04	0.21	0.26	1.03
122	MedicalInst	0.01	0.17	0.18	0.67
123	Jewelry	0.04	0.21	0.25	0.97
124	Aircraft	0.02	0.18	0.20	0.94
125	MiscManu	-0.08	0.18	0.11	0.96
126	Construction	0.08	0.08	0.17	0.20
127	Electricity	0.10	-7.05	-7.06	-7.40
128	WaterSupply	0.08	0.04	0.13	0.27
129	Railways	-0.09	-0.09	-0.18	-0.02
130	LandTransp	-0.12	0.03	-0.09	-0.17
131	WaterTrans	-0.83	-0.47	-1.31	-1.02
132	AirTrans	-0.08	0.21	0.13	1.12
133	TranspServ	-0.40	-0.15	-0.55	-0.69
134	Storage	-0.11	0.00	-0.10	-0.25
135	Communic	0.02	0.07	0.09	0.58
136	Trade	-0.11	0.01	-0.10	-0.26
137	HotelRest	-0.01	0.03	0.02	0.00
138	Banking	0.01	-0.04	-0.03	0.06
139	Insurance	-0.08	0.04	-0.05	0.19
140	OwnDwell	0.24	0.22	0.48	0.91
141	Education	0.17	0.17	0.34	0.71
142	MedicalServ	0.17	0.17	0.35	0.67
143	BusinServ	-0.23	0.13	-0.10	0.90
144	ComputServ	-0.05	0.29	0.24	2.09
145	LegalServ	0.08	0.23	0.32	1.16
146	RealEstate	0.14	0.18	0.33	0.80
147	RentingME	0.12	0.16	0.29	0.67
148	SocialServ	0.03	0.09	0.13	0.13
149	OtherServ	-0.01	0.28	0.27	1.87
150	PublicAdmin	0.10	0.10	0.20	0.24

Figure 6. The irrelevance of the split of subsidy payments between producers and consumers

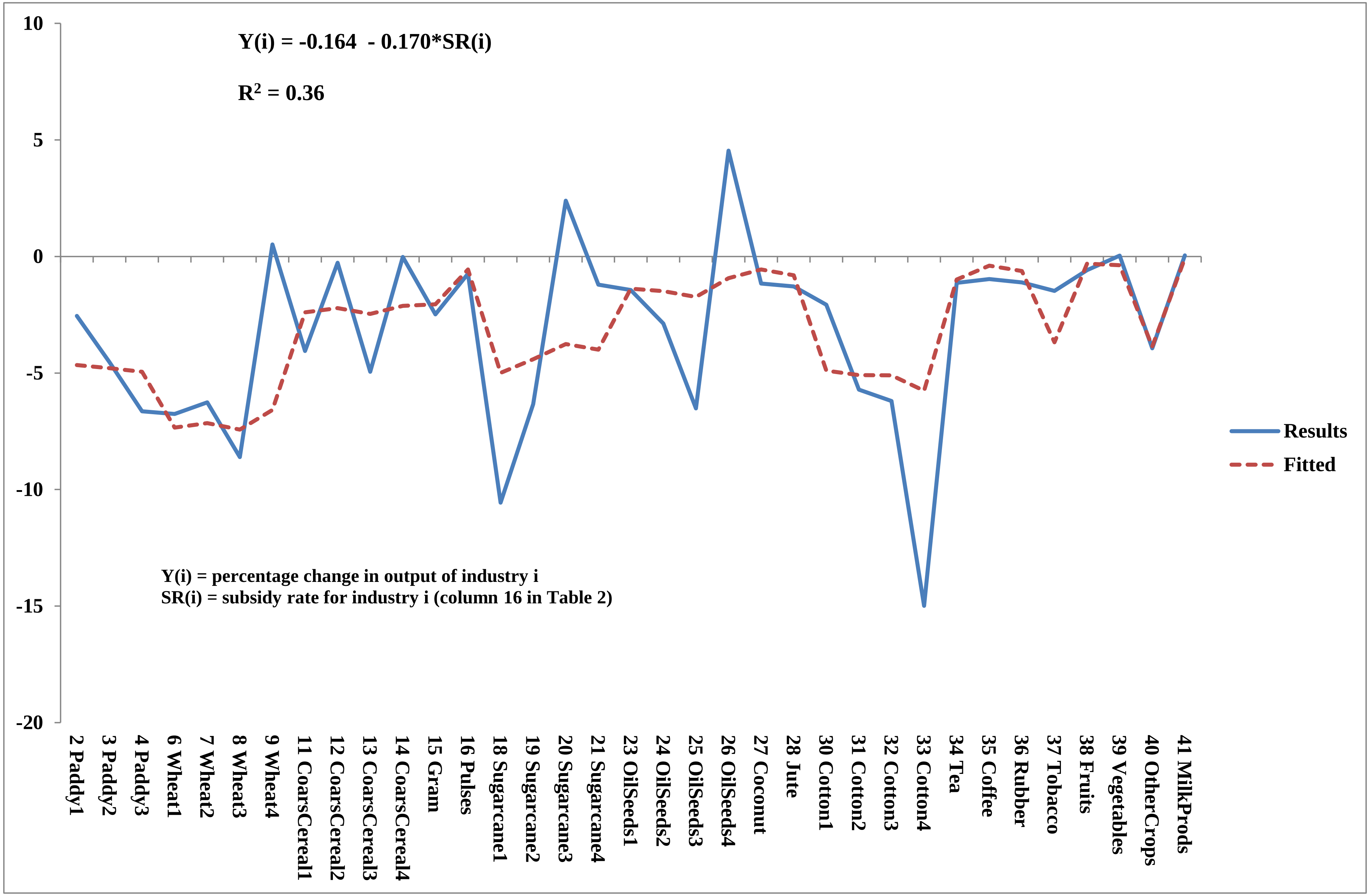


The figure shows supply as a function of price to producers (PtoP) and demand as a function of price to consumers (PtoC). PtoP is the price paid to producers by consumers plus the production subsidy per unit of output. PtoC is the price paid to producers by consumers less the consumption subsidy per unit of consumption. Together, the two sets of subsidies explain the gap between PtoP and PtoC. Whether the subsidies are paid to producers or consumers or split between them makes no difference to the figure or the conclusions that can be drawn from it.

are important for determining the Y(i)s for agricultural industries. This impression is confirmed in Figure 7 which shows large gaps between NCAER-VU values for percentage changes in industry outputs and fitted values computed from equation (11).

What does NCAER-VU know that the regression in (11) does not capture? For example, why does NCAER-VU show a much less favourable outcome for Cotton4 and a much more favourable outcome for Oilseeds4 than are indicated by the regression equation? The answer is competitive effects within the oilseeds group of industries and within the cotton group. Cotton4 is intensive in the use of Fertilizers, accounting for 7.61 per cent of Fertilizer use in cotton production but only 3.90 per cent of cotton output [columns (4) and (2) in Table 2]. Thus, removal of Fertilizer subsidies harms Cotton4 in competition with other cotton industries, leading to a strongly negative output result for Cotton4 (-11.33 per cent) in column (1) of Table 6, which explains most of the strongly negative result for Cotton4 (-14.98 per cent) in column (4). By contrast, Oilseeds4 is a light user of Fertilizers, accounting for 0.56 per cent of Fertilizer use in oilseed production but 3.39 per cent of oilseed output [columns (4) and (2) in Table 2]. Thus, removal of Fertilizer subsidies favours Oilseeds4 in competition with other oilseed industries, leading to a positive output result for Oilseeds4 (5.51 per cent) in column (1) of Table 6.

Figure 7. NCAER-VU results for the output of Agricultural industries explained by initial subsidy rates



To test the competitiveness idea, we expanded the regression described in (11) to include variables that take account of the subsidy for each industry relative to the subsidy applied to other industries producing the same crop. For example, we included variables that take account of the difference between the subsidy rate for Paddy1 [26.4 per cent, column (16), Table 2] and the average subsidy rate over Paddy1, Paddy2 and Paddy3 [27.3 per cent]. We expect the coefficients on these additional variables to be negative. The loss of a high relative subsidy will have a negative effect on an industry, beyond what can be explained simply by the level of the subsidy. The result from the expanded regression is:

$$\underset{(0.34)}{Y(i) = -0.575} \; \underset{(0.02)}{-\,0.146*SR(i)} \; \underset{(0.99)}{-\,2.206*D\_P(i)} \; \underset{(0.31)}{-\,1.615*D\_W(i)} \; \underset{(0.76)}{-\,2.554*D\_CC(i)}$$

$$\underset{(0.22)}{-\,1.619*D\_SC(i)} \; \underset{(0.35)}{-\,2.173*D\_OS(i)} \; \underset{(0.31)}{-\,2.298*D\_COT(i)} \qquad R^2 = 0.92 \qquad (12)$$

where

D_P(i) is the deviation of i's subsidy rate from the average subsidy rate for Paddy industries if i is a Paddy industry, else 0;

D_W(i) is the deviation of i's subsidy rate from the average subsidy rate for Wheat industries if i is a Wheat industry, else 0;

D_CC(i) is the deviation of i's subsidy rate from the average subsidy rate for Coarse cereal industries if i is a Coarse cereal industry, else 0;

D_SC(i) is the deviation of i's subsidy rate from the average subsidy rate for Sugarcane industries if i is a Sugarcane industry, else 0;

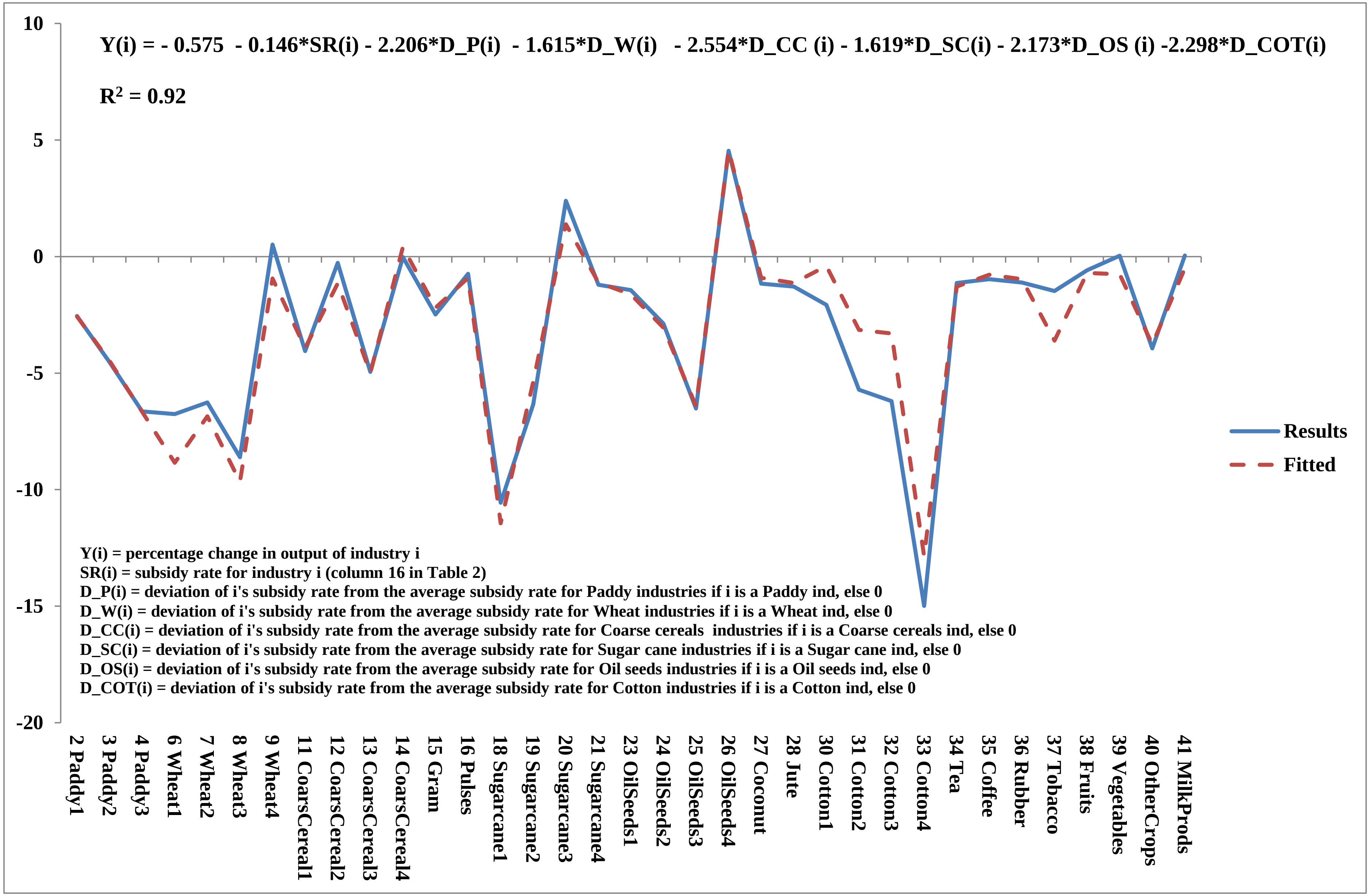
D_OS(i) is the deviation of i's subsidy rate from the average subsidy rate for Oilseed industries if i is an Oilseed industry, else 0; and

D_COT(i) is the deviation of i's subsidy rate from the average subsidy rate for Cotton industries if i is a Cotton industry, else 0.

The coefficients on all variables on the right hand side of (12) have the expected negative sign. The R-squared is 0.92 implying that (12) captures the main mechanisms in NCAER-VU that are important for determining the Y(i)s for agricultural industries. This is confirmed in Figure 8 which shows small gaps between NCAER-VU simulation values for percentage changes in industry outputs and fitted values computed from equation (12).

Although the gaps in Figure 8 are small, they have one obvious systematic feature: the fitted values for the 4 cotton industries lie noticeably above the NCAER-VU simulated values. A factor recognized by NCAER-VU but missing in (12) is exposure to price-sensitive export markets. While most of Indian agriculture faces little competition from imports and has little dependence on exports, this is not true for cotton. There are no direct imports or exports of cotton. However, there are large indirect exports through Cotton textiles and Apparel. Removal of subsidies from cotton increases input costs to these price-sensitive exporting industries. Via high export demand elasticities, this reduces their exports and consequently their demand for inputs of cotton. This connection of cotton output to high-elasticity, price-sensitive export markets is built into NCAER-VU but not into (12). Consequently, (12) understates the NCAER-VU projection of damage to cotton industries from subsidy removal.

Figure 8. NCAER-VU results for the output of Agricultural industries explained by initial subsidy rates and dummies for relative subsidy rates



To test the quantitative importance of export connection in explaining the NCAER-VU output results for agricultural products, we expanded the regression described in (12) to include a variable [PS_X(i)] that reflects the share of each industry's output that is sold in price-sensitive export markets. This variable is defined by:

$$\begin{aligned} PS\_X(i) &= T4(i)*\gamma(i)*\left[SRFEP(i)+\left(\sum_{k\in Agric} CSH(k,i)*SR(k)\right)\right] \\ &+ \sum_{\substack{j\in Ind \\ j\neq i}} T1(i,j)*T4(j)*\gamma(j)*\left[SRFEP(j)+\left(\sum_{k\in Agric} CSH(k,j)*SR(k)\right)\right] \end{aligned} \tag{13}$$

In simple terms, T4(i) is the export share in i's sales; $\gamma(i)$ is the absolute value of the export demand elasticity for commodity i; SRFEP(i) is the combined Fertilizer, Electricity and production subsidy rate for commodity i; CSH(k,i) is the share of k in industry i's costs; T1(i,j) is the share of i's sales that go to industry j as an intermediate input; and SR(k) is the total subsidy rate applying to industry k. The existence of mixing industries means that these definitions are not quite adequate. More precise definitions are given in the Appendix.

The first term on the right hand side of (13) is a spreadsheet calculation of the effect of subsidy removal on industry i's output via the *direct* exports of commodity i. It takes account of the importance exports in the sales of i [T4(i)], the sensitivity of exports to changes in their price [$\gamma(i)$], and an estimate of the percentage price change induced by subsidy removal [$SRFEP(i)+\sum_{k\in Agric} CSH(k,i)*SR(k)$]. In estimating the induced price movement in i relevant for export markets, we take account of subsidies on Fertilizer, Electricity and production: sales subsidies do not apply to exports. We also take account of subsidies on agricultural inputs to the production of i: the total subsidy rate SR(k) is relevant here because the price that industry i pays for agricultural product k depends on all of the subsidies (including sales subsidies) applying to k.

The second term on the right hand side of (13) is a spreadsheet calculation of the effect of subsidy removal on industry i's output via *indirect* exports. This encompasses the first round implications for i's output of movements in j's output (for j $\neq$ i) caused by movements in j's exports. The induced movement in j's output is estimated in the same way as the induced export-related movement in i's output. The implication for the output of i is then estimated taking account of the share of the sales of i that goes to industry j as an intermediate input.

With PS_X(i) included, our regression explanation of the results for agricultural outputs becomes:

$$\begin{aligned} Y(i) = &- \underset{(0.27)}{0.376} - \underset{(0.03)}{0.128}*SR(i) - \underset{(0.76)}{2.223}*D\_P(i) - \underset{(0.24)}{1.633}*D\_W(i) - \underset{(0.59)}{2.572}*D\_CC(i) \\ &- \underset{(0.17)}{1.637}*D\_SC(i) - \underset{(0.27)}{2.191}*D\_OS(i) - \underset{(0.24)}{2.316}*D\_COT(i) - \underset{(0.09)}{0.384}*PS\_X(i) \quad R^2 = 0.95 \end{aligned} \tag{14}$$

The signs on all variables on the right hand side of (14) are negative as expected. The standard errors are even smaller than in equation (12). The fit has been improved from an R-squared of 0.92 in equation (12) to an R-squared of 0.95 in equation (14). As can be seen by comparing Figures 8 and 9, the inclusion of PS_X(i) has strongly improved the fit of the regression equation to the NCAER-VU results for the cotton industries. This confirms our hypothesis that export connection was a missing factor in equation (12).

The process of adding explanators to the right hand side of the regression equation could be continued indefinitely. For example, on looking at Figure 9 we could ask: what does NCAER-VU know about Tobacco which is not captured in (14), causing the fitted result to underestimate the simulated result. We suspect that the factor missing from (14) but which is included in NCAER-VU is that Tobacco faces an atypically low price elasticity of demand, implying that damage to its output from increased prices is muted. While this idea could be checked out by adding further terms to our regression equation, it is clear at this stage that we have already captured the major features of NCAER-VU that are important for the results we are explaining.

3.2(b). Real farm income and the prices of food products

The two principal objectives of agricultural subsidies are to support farm incomes and to reduce the prices to households of food products. In this subsection we examine the efficacy of the current set of agricultural subsidies in India for achieving these objectives.

The effect of Fertilizer and Electricity subsidies on real farm income

Columns (1) to (4) of Table 7 show the effects on real farm income and its components of removing agricultural subsidies. The striking result in the table is that removal of subsidies on Fertilizer and Electricity inputs increases farm income. In column (1), removal of Fertilizer subsidies increases real farm income by 1.041 per cent. In column (2), removal of Electricity subsidies increases farm income by 0.893 per cent. Removing both these input subsidies increases real farm income by 1.922 per cent. Far from supporting farm income, NCAER-VU implies that Fertilizer and Electricity subsidies harm farm income.

Removing Fertilizer and Electricity subsidies has two broad effects on farm income: one negative and one positive. The negative effect is that removing subsidies increases costs of production and contracts outputs[20], leading to reduced demand for factors that contribute to farm income (agricultural land, and capital and labour used in farm industries). The positive effect is that removing these particular subsidies causes substitution in the production of agricultural products towards factors that contribute to farm income and away from Fertilizer and Electricity that do not contribute to farm income. Even with a moderate substitution elasticity (0.5) between factors that contribute to farm income and factors that don't, the positive substitution effect dominates the negative output-contraction effect.

By switching demand in agricultural industries onto primary factors, removal of Fertilizer and Electricity subsidies causes a much larger percentage increase in the demand for agricultural land (which is used entirely in agriculture) than in the demands for capital and labour (which are used throughout the economy and are mobile between sectors). Consequently, the rental price of agricultural land rises sharply relative to the prices for using capital and labour. Thus, in row 3 of Table 7 there are large positive entries in columns (1), (2) and (3). Combined removal of Fertilizer and Electricity subsidies increases real rents (and therefore real incomes) from land by 4.170 per cent.

Despite substitution towards capital and labour in agricultural industries, rows 1 and 2 of Table 7 show that removing Fertilizer and Electricity subsidies has close to zero effects on capital and labour income in agriculture [-0.077 and 0.092 in column (3)]. Removing these subsidies increases employment of capital and labour in agriculture but reduces real rental

[20] Notice that column (3) of Table 6 shows negative output effects for almost all agricultural industries from removing Fertilizer and Electricity subsidies.

Figure 9. NCAER-VU results for the output of Agric. industries explained by initial subsidy rates, relative subsidy rates & exposure to price-sensitive exports

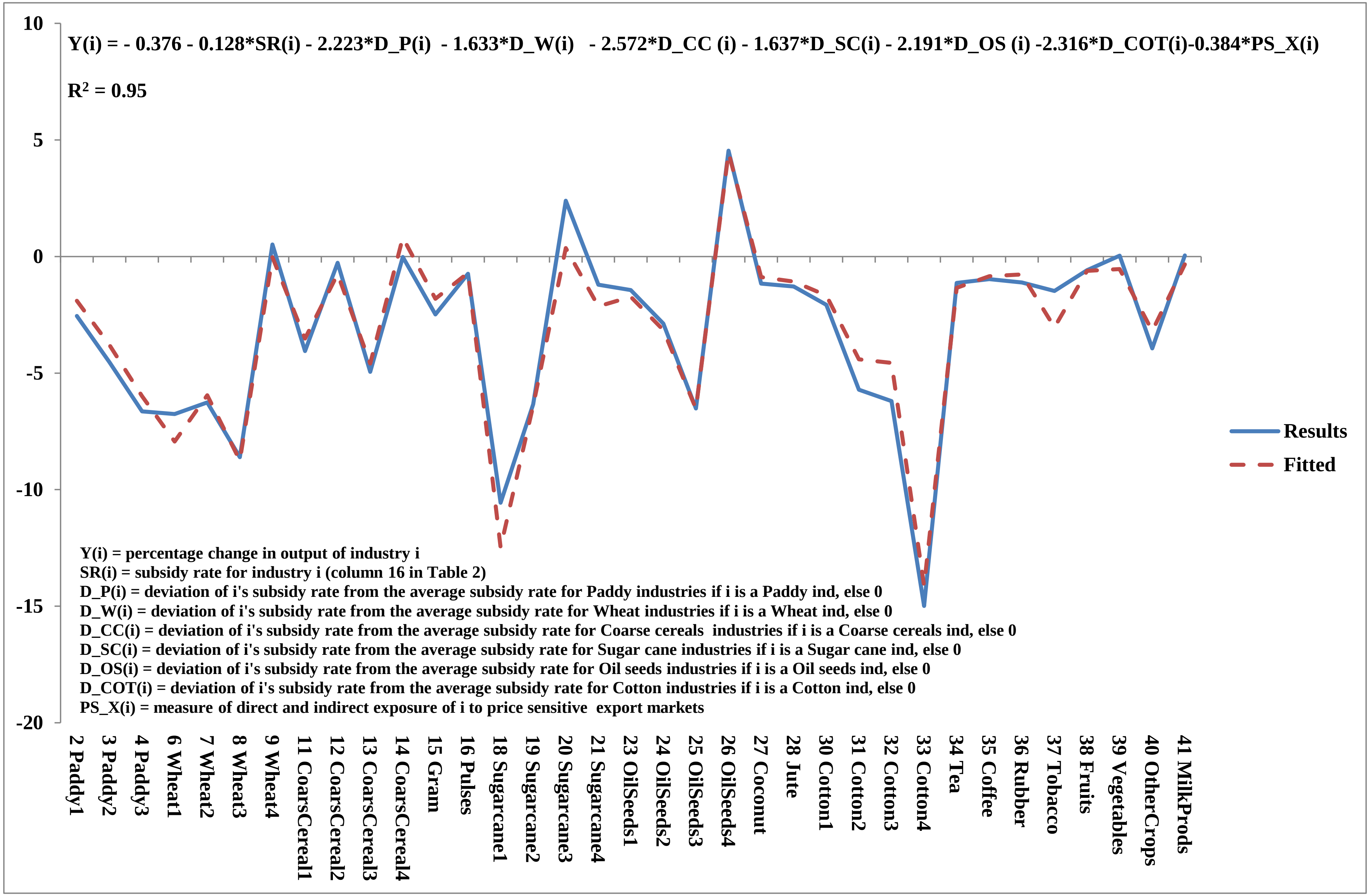


Table 7. Percentage effects on real (CPI deflated) farm income of removing agricultural subsidies on Fertilizer, Electricity, production and sales, and of an income enhancing revenue-neutral subsidy package

	Components of real farm income	Fertilizer (1)	Electricity (2)	Fertilizer & Electricity (3)	Fertilizer, Electricity, production & sales (4)	Production and sales (4a) = (4) – (3)	Revenue-neutral farm income enhancing package (5) = (3)-0.44* (4a)
1	Capital	-0.042	-0.018	-0.077	-3.572	-3.495	1.474
2	Labour	0.027	0.080	0.092	-3.453	-3.545	1.665
3	Land	2.277	1.900	4.170	-2.610	-6.780	7.178
4	Total real farm income	1.041	0.893	1.922	-3.089	-5.011	4.145

prices for capital and real wage rates for labour. It turns out that from the point of view of agricultural income, the reductions in real factor prices for capital and labour closely offset the increases in their agricultural employment.

Why does removing Fertilizer and Electricity subsidies reduce the real costs of using capital and labour even in agriculture in which demands for capital and labour increase? In economy-wide terms we can think of real GDP as a function of capital, labour, land, technology and efficiency (the triangles considered in subsection 3.1). With factor inputs and technology held constant, the movement in real GDP is confined to the relatively small efficiency effects. Real GDP is also equal to returns to each of the factors plus net indirect taxes, all divided by the price deflator for GDP. With a sharp increase in real rental rates on land, and an increase in net indirect taxes (withdrawal of subsidies), there must be a reduction in the average of the real returns (rentals and wage rates) accruing to capital and labour. In fact, in simulations 1) and 2) the real rental rate for capital and the real wage rate for labour both fall, and with capital and labour mobile between sectors these falls apply throughout the economy, including the agricultural sector.

The effect of production and sales subsidies on real farm income

Column (4) shows the effects on farm income and its components of removing all agricultural subsidies. Production and sales subsidies do not cause substitution effects within agricultural industries. Consequently, removing them has only the negative output-contraction effect mentioned above. Production and sales subsidies are large relative to Fertilizer and Electricity subsidies (Rs 870,107m compared with Rs 386,070m), allowing the negative effect on farm income of removing production and sales subsidies to overwhelm the positive effect of removing Fertilizer and Electricity subsidies. Thus, column (4) in Table 7 shows negative entries for total real farm income and all its components.

The difference between columns (4) and (3), see column (4a), shows that removal of production and sales subsidies reduces real farm income by 5.011 per cent, with a particularly strong effect on land income (a real reduction of 6.780 per cent). The contraction in agricultural demand for primary factors induced by removal of production and sales subsidies has a strong negative effect on the rental rate of agricultural land (which is employed only in agriculture) relative to its effects on the real prices of capital and labour (which are employed throughout the economy). However, capital and labour incomes in the agricultural sector fall significantly (3.572 per cent and 3.453 per cent) reflecting a combination of reduced use of these factors in agriculture (output contraction effect) and reduced economy-wide real capital rentals and real labour wage rates.[21]

A revenue-neutral farm income enhancing package

Fertilizer and Electricity subsidies reduce farm income while production and sales subsidies increase farm income. Consequently, at no budgetary cost (a fixed total expenditure on subsidies) farm incomes in India could be increased by converting Fertilizer and Electricity subsidies into production and sales subsidies.

This idea is illustrated by a back-of-the-envelope calculation in column (5) of Table 7 which shows the effects of eliminating Fertilizer and Electricity subsidies [column (3)] combined with the effects of increasing production and sales subsidies by 44 per cent [calculated as the negative of 0.44 times column (4a)]. Why 44 per cent? Removal of the

[21] Removal of subsidies worth about 1.7 per cent of GDP causes a reduction in real factor prices for capital and labour of about 1.7 per cent. The welfare of capital owners and workers could be safeguarded by cuts in taxes.

Fertilizer and Electricity subsidies would allow a budget-neutral 44 per cent increase in production and sales subsidies (44= 100*386,070/870,107).

With this reorganization of subsidies, real farm income increases by 4.145 per cent. There are increases in all components of farm income, with a strong increase, 7.178 per cent, in real land rents. Returning to Table 5, we can calculate the GDP effect of subsidy reorganization: a gain of 0.135 per cent [=0.156 – 0.44*(0.204 – 0.156)]. Similarly there is an overall welfare gain measured by consumption of 0.185 per cent [= 0.202-0.44*(0.241-0.202)].

The effect of agriculture subsidies on food security

Table 8 provides NCAER-VU results relevant for assessing the effect of agricultural subsidies on food prices and consumption of food products (often referred to as food security variables).

Removal of agricultural subsidies increases food prices and reduces food consumption. Price increases and consumption reductions reflect the initial rates of subsidies. Thus, for example, panel 4 (removal of all agricultural subsidies) shows particularly sharp price and quantity movements for Paddy, Wheat, Sugarcane and Other crops, all of which have high subsidy rates [column (16), Table 2].[22]

Unlike the situation with farm income, from the point of view of food security, the form of agricultural subsidies is not critical. This can be seen by comparing the results in Table 8 in the last row of panel 3 (Fertilizer and Electricity subsidies) with those in the last row of panel 4a (production and sales subsidies). Recall that Fertilizer and Electricity subsidies are 44 per cent as large as production and sales subsidies. If we multiply the average price and quantity movements (4.90 and -0.47 per cent) in panel 4a by 0.44, we obtain 2.17 and -0.21, approximately the average price and quantity movements in panel 3. Agricultural subsidies, whatever their form, reduce the costs of supplying food to households approximately in proportion to the value of the subsidy, which is then reflected in the prices that households pay. Consistent with this, panel 5 in Table 8 shows that reorganizing agricultural subsidies in a budget-neutral way has little effect on average prices for food products or on food consumption.

3.2(c). Outputs of non-agricultural commodities/industries, 42 to 150

In this subsection we return to Table 6 and look briefly at the output results for non-agricultural industries.

Removal of all agricultural subsidies [column (4)] reduces outputs of Fertilizer and Electricity (commodities 87 and 127) directly by causing substitution in agricultural industries against these inputs. The percentage reduction in Fertilizer output [20.68 per cent, contributed mainly by the reduction in Fertilizer subsidies, column (1)] is much greater than that in Electricity output [7.40 per cent, contributed mainly by the reduction in Electricity subsidies, column (2)]. This is because the use of fertilizer is concentrated in agriculture whereas electricity is used throughout the economy.

Cotton textiles (commodity 67), Sugar (58), Other edible oil (61), Woollen textiles (68), Khadi (66) and Apparel (73) all show output loses in column (4) of Table 6 of about 3 per cent or more. These commodities have significant exports and rely on inputs of subsidized agricultural products. Consequently they are damaged by a loss in international

[22] Cotton and Tobacco also have high subsidy rates but we do not include them among food products.

Table 8. Percentage effects on real prices[1] and consumption (quantities) of food products from removing agricultural subsidies on Fertilizer, Electricity, production and sales, and of an income enhancing revenue-neutral subsidy package

	Fertilizer (1)		Electricity (2)		Fertilizer & Electricity (3)		Fertilizer, Electricity, production & sales (4)		Production and sales (4a) = (4) – (3)		Revenue-neutral farm income enhancing package (5) = (3) – 0.44*(4a)	
Food prod.	***Price***	***Quantity***	***Price***	***Quantity***	***Price***	***Quantity***	***Price***	***Quantity***	***Price***	***Quantity***	***Price***	***Quantity***
Paddy	2.88	-0.42	3.17	-0.46	6.12	-0.86	21.34	-2.68	15.22	-1.82	-0.63	-0.05
Wheat	2.79	-0.41	2.68	-0.39	5.50	-0.77	36.39	-3.94	30.89	-3.17	-8.21	0.64
Coarse cereal	3.44	-0.51	1.68	-0.24	5.18	-0.73	8.46	-1.24	3.28	-0.51	3.72	-0.50
Gram	1.87	-0.27	1.64	-0.23	3.53	-0.49	7.14	-1.07	3.61	-0.58	1.93	-0.23
Pulses	1.36	-0.19	0.66	-0.07	2.03	-0.26	1.16	-0.22	-0.87	0.04	2.42	-0.28
Sugarcane	2.98	-0.44	1.69	-0.24	4.71	-0.66	18.00	-2.34	13.29	-1.68	-1.19	0.09
OilSeeds	2.47	-0.36	0.62	-0.07	3.11	-0.42	4.66	-0.73	1.55	-0.31	2.42	-0.28
Coconut	1.47	-0.21	0.12	0.01	1.59	-0.19	-0.40	0.02	-1.99	0.21	2.47	-0.28
Fruits	0.70	-0.09	0.54	-0.05	1.24	-0.14	-1.99	0.28	-3.23	0.42	2.67	-0.33
Vegetables	0.86	-0.11	0.60	-0.06	1.46	-0.17	-1.36	0.17	-2.82	0.34	2.71	-0.32
OtherCrops	2.52	-0.37	1.76	-0.25	4.31	-0.60	20.82	-2.62	16.51	-2.02	-3.02	0.30
MilkProds	0.50	-0.09	0.39	-0.05	0.89	-0.14	-0.92	0.17	-1.81	0.31	1.69	-0.28
PoultEggs	0.25	-0.03	0.18	0.00	0.44	-0.02	0.35	-0.16	-0.09	-0.14	0.48	0.04
OthLiveSt	0.19	-0.01	0.10	0.03	0.29	0.02	2.16	-0.61	1.87	-0.63	-0.54	0.30
Fishing	-0.56	0.19	-0.38	0.15	-0.94	0.35	-2.66	0.64	-1.72	0.29	-0.18	0.22

Table 8 continues …

Table 8 continued …

Food prod.	Fertilizer (1)		Electricity (2)		Fertilizer & Electricity (3)		Fertilizer, Electricity, production & sales (4)		Production and sales (4a) = (4) – (3)		Revenue-neutral farm income enhancing package (5) = (3) – 0.44*(4a)	
	Price	***Quantity***	***Price***	***Quantity***	***Price***	***Quantity***	***Price***	***Quantity***	***Price***	***Quantity***	***Price***	***Quantity***
Sugar	1.17	-0.19	0.61	-0.08	1.79	-0.26	7.31	-1.28	5.52	-1.02	-0.66	0.19
Khandsari	1.19	-0.19	0.62	-0.08	1.82	-0.27	7.37	-1.29	5.55	-1.02	-0.64	0.18
Vanaspati	0.86	-0.13	0.12	0.02	0.98	-0.12	0.42	-0.13	-0.56	-0.01	1.23	-0.12
OthEdibleOil	0.83	-0.13	0.11	0.02	0.94	-0.11	0.58	-0.16	-0.36	-0.05	1.10	-0.09
TeaCoffee	0.02	0.02	-0.14	0.06	-0.12	0.09	-1.12	0.16	-1.00	0.07	0.32	0.06
MiscFoodProd	0.27	-0.02	0.18	0.00	0.46	-0.02	0.68	-0.18	0.22	-0.16	0.36	0.05
Average[2]	1.25	-0.17	0.98	-0.11	2.25	-0.27	7.15	-0.74	4.90	-0.47	0.08	-0.06

[1] These are price movements relative to the movement in the CPI. In this table we show estimates of movements in real purchasers prices to households, assuming that margins are 25 per cent of purchasers prices and that the prices of margins services are not affected agricultural subsidies.

[2] Calculated using household expenditure weights.

competitiveness when agricultural subsidies are removed. The only other non-agricultural commodity shown in column (4) of Table 6 with an output loss of more than 3 per cent is Animal services (42). Demand for this product contracts with decline in agricultural output.

Five non-agricultural commodities have output increases in column (4) of Table 6 of about 1.5 per cent or greater. All of these commodities are trade exposed: Mica (commodity 56) faces overwhelming import competition while Communication equipment (112), Other services (149), Non-ferrous metals (100) and Computer services (144) have significant export shares in their sales. None of these commodities relies on agricultural inputs and all experience enhanced international competitiveness via economy-wide reductions in the real costs of using capital and labour.

4. Concluding remarks

Despite the availability of CGE templates [e.g. Horridge (2000)] and associated software [e.g. Harrison *et al.* (2014)], creation of a policy-relevant CGE model is still a major task. As described in section 2, time-consuming hard work is required to convert published input-output tables into a form suitable for CGE modelling. Input-output statisticians in official agencies still have in mind Leontief's input-output model. Consequently, they focus on intermediate input flows and final demands, demand-side concepts, with relatively little attention to factor prices and quantities, supply-side concepts. From the point of view of CGE modelling, weaknesses of the input-output data published by India Statistics, shared by data from many other official agencies, include:

- lack of disaggregation of value added for each industry into returns to labour, capital and land. For a CGE model, disaggregation of value added is required so that we can simulate competition between industries for scarce primary factors.
- use of indirect allocation of imports meaning that each commodity flow is an aggregate of an import and domestic flow. For a CGE model, disaggregation of each flow into an import component and a domestic component is required so that we can simulate import/domestic substitution in response to changes in tariffs, the exchange rate and other variables that affect international competitiveness.
- representation of the use of a margin commodity (e.g. retail trade) to facilitate all flows to an agent (e.g. households) as a single purchase and representation of indirect tax collections on all flows to an agent as a single payment. For a CGE model, we need to identify the particular flows (e.g. purchases of apparel) to an agent (e.g. households) that give rise to the use of a margin service (e.g. retail trade) and to tax payments. A matrix of data, rather than a row, is required for each margin service and for indirect taxes so that a CGE model can adequately represent the demand for margin services and the implications for government revenue collection of structural changes. Matrices are also necessary for distinguishing between purchasers prices (that motivate demand decisions) and basic prices (that motivate production decisions).
- and recording of investment expenditures as a single column, showing economy-wide investment expenditure on each commodity. For a CGE model, we require a matrix of investment expenditures, identifying investment expenditures by each industry on each commodity. This is necessary so that we can simulate the effects of changes in commodity prices on the cost of investment in each industry and the consequent changes in investment by industry. Then we can work out the implications for capital-supplying industries (e.g. construction) and the rest of the economy.

In building the first version of the NCAER-VU model we satisfactorily supplemented published input-output data on indirect taxes and tariffs by using unpublished data supplied by India Statistics. In dealing with value added, imports and investment expenditures we have adopted temporary procedures that we hope will be improved upon in future research. For disaggregating value added, we used GTAP data on an industry classification that differs markedly from that in the India Statistics input-output data. For imports of a given commodity, we assumed that the same import/domestic share applies to every flow. For investment expenditures, we assumed for every industry the same ratio of total investment to capital income and the same commodity structure. With regard to margins, we have simply assumed that there aren't any. Consequently in its current form, NCAER-VU treats demands for Road transport, Retail trade etc as though they are direct demands, not linked to the flows of other goods and services.

Beyond making improvements in the input-output data of the NCAER-VU model, there are several other major data tasks on the agenda for future research. Among these are: updating the database from its current year of 2007-8; and inclusion in the model of capital stocks by industry, government accounts, the balance of payments and foreign assets and liabilities. All of this work is required to make NCAER-VU suitable for dynamic analysis of the type conducted with CoPS models of Australia, the U.S. and several other countries (see, for example, Dixon and Rimmer, 2002). Other additions to the NCAER-VU model will be a disaggregation of the household sector and inclusion for each industry of pollution coefficients (e.g. CO_2-equivalent emissions per unit of output). These additions will allow NCAER-VU to project the effects of policy changes on distributional and environmental variables.

However, as emphasized in section 1, applications cannot wait for the fully developed model. Applications supported by BOTE calculations should proceed in parallel with model development. Applications guide development. For example, the developments described in subsection 2.4 were guided and motivated by our initial application of NCAER-VU to the analysis of agricultural subsidies. Although the NCAER-VU model is at an early stage of development, the results in section 3 provide potentially important insights on the effects of agricultural subsidies. We found that:

- agricultural subsidies are worth about 2.5 per cent of GDP with about 1/3rd being subsidies on inputs of Fertilizer and Electricity to agricultural industries and about 2/3^{rds} being subsidies on production and sales of agricultural products.
- agricultural subsidies inflict a GDP loss (a dead-weight loss) on India of about 0.20 per cent, most of which is associated with the subsidies on Fertilizer and Electricity. The percentage loss in economic welfare measured by foregone consumption is about 0.24 per cent.
- agricultural output is about 2.3 per cent greater with subsidies than it would be without subsidies.
- agricultural subsidies increase output and exports of Cotton textiles, Edible oil, Woollen textiles, Khadi and Apparel, but reduce output and exports of Communication equipment, Non-ferrous metals and Computer services.
- about 20 per cent of the output of Fertilizer and 7 per cent of the output of Electricity in India depend on agricultural subsidies.
- Fertilizer and Electricity subsidies do not contribute to the objective of supporting farm income. In fact, they reduce real farm income by about 2 per cent. By contrast, India's production and sales subsidies on agricultural products boost real farm income by about 5 per cent.

- all of the current agricultural subsidies contribute positively to the objective of food security. The subsidies reduce food prices relative to the CPI by about 7 per cent and increase food consumption by about 0.7 per cent.
- if government provision of Fertilizer and Electricity subsidies to the agricultural sector were phased out and replaced with additional provision of agricultural production and sales subsidies, then real farm income would be increased by about 4 per cent with no deterioration in the public sector budget, almost no effect on food security, and gains in GDP and overall welfare of about 0.13 per cent and 0.18 per cent.

Appendix. Defining the terms in equation (13)

In precise terms the concepts on the right hand side of equation (13) are defined as follows:

Agric is the set of 41 agricultural commodities/industries;

Ind is the set of all industries;

T4(i) is the share of the economy-wide output of industry i's commodity (e.g. paddy if i equals Paddy1, Paddy2 or Paddy3) that is sold in price-sensitive[23] export markets;

γ(i) is the absolute value of the export demand elasticity for commodity i;[24]

for i $\in$ Agric, SRFEP(i) is the input & production subsidy rate applying to the overall industry to which i belongs [e.g. SRFEP(Paddy1) is the input & production subsidy rate applying to paddy] and is calculated as the combined Fertilizer, Electricity and production subsidies paid to industries [e.g. Paddy1, Paddy2, Paddy3] producing the product of industry i (paddy) expressed as a percentage of the basic value of the output of that product [e.g. the basic value of paddy output];

for i $\notin$ Agric, SRFEP(i) equals zero;

CSH(k,i) is the share of k in industry i's costs (or output);

if k is one of the 35 agricultural commodities/industries listed in Table 2 then SR(k) is, as defined earlier, the total subsidy rate applying to k [column (16)];

if k is one of the 6 mixing industries, then SR(k) is the average of the total subsidy rates applying to the component industries;

if k is not in Agric, then SR(k) equals zero; and

T1(i,j) is the share of the economy-wide output of industry i's commodity (e.g. paddy if i is Paddy1) that is sold to industry j as an intermediate input.

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[23] In the current version of NCAER-VU, only exports of manufactures, mining and selected services (e.g. communications) are treated as price-sensitive. Exports of other commodities (including agricultural commodities) are lumped together and exported as a composite commodity. The price of an individual product in this composite has little impact on exports of the product. This treatment of exports is not satisfactory and will be revised in future applications of NCAER-VU.

[24] In NCAER-VU the values of these elasticities range between 1.8 and 10, with an average value of about 5.

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