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CGE Applications in Development Economics

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Abstract This paper begins with an informal history of developing country CGE models, going on to specification and closure, and finally describes a few models with financial extensions. Sectoral detail is central to CGE analysis, but after an initial sketch of an *n*-sector system most of the discussion focuses on the models' "closures" or patterns of macroeconomic causality, because they strongly influence their sectoral results. Particular attention is paid to the ways in which international trade and financial flows are fitted into applied models.

Two planners, Leif Johansen and Hollis Chenery, were the intellectual leaders in the creation and use of computable general equilibrium (CGE) models in development economics. The first applications were meant to be models for planning. Although that term has long since vanished from polite economic discourse I would argue that the main practical application of CGE models is to explore possible responses of the economic system to shifts in policy regarding market-based interventions (taxes, changes in the exchange rate, fiscal spending, etc.) *and* more direct actions such as supporting specific investment projects through an agency such as a development bank. Both Leif and Hollis accepted the need for state intervention along such lines.

A second point is that all CGE models are built in a Keynesian framework. The models themselves and the data that they rely on explicitly incorporate Keynes's postulate that income must equal expenditure. Their accounting structure has a close relationship to the subtle equilibrium model in chapter 19 of the *General Theory* (Keynes, 1936). Once their parameters have been calibrated to a base year social accounting matrix or SAM, CGE models *are* in accounting equilibrium up to the numerical precision of the computer at hand – the "computable" part boils down to asking how macro and sectoral flow variables shift when a pre-existing equilibrium is shocked. The models never were and are *not* Walrasian. They are exercises in macroeconomic accounting to the core, and that is how they should be understood.

Following Velupillai and Zambelli (2010) one can put the foregoing more strongly. Standard CGE applications all rely on textbook real analysis, based on Zermelo-Fraenkel set theory and the axiom of choice. Using standard numerical procedures a model-builder can compute continuous approximations to comparative static and dynamic variations around a SAM. Even if it has been put together on the basis of unsupported assumptions and dubious procedures, the principal virtue of the matrix is that its accounts balance to a “good approximation” – both before and after it is perturbed. The outcomes of numerical simulations on a SAM are useful only insofar as they are “conjoined to those intangible non-formal concepts like [a model-builder’s] intuition, experience, and insight” (p.20).

Johansen and Chenery had those virtues in abundance, but they never thought that they were replicating an Arrow-Debreu economy, an exercise which Velupillai and Zambelli argue is computationally intractable in any case. The over-simplified gist is that an entity with finite computing capacity (say a human being or even a universal Turing machine) cannot solve a problem in which the agents involved confront a continuum of choices.

Consistent macro accounting limits the degrees of freedom available to a CGE model. The qualitative character of its results depends crucially on how the available free variables are utilized by the macroeconomic causal structure or “closure” that is imposed upon the numbers. This fact is both a strength and a weakness of the methodology. One thing that one learns as an applied development economist is that there can be big differences in the ways that economies appear to behave – one may have substantial reserves of underemployed or surplus labor, another may be foreign exchange constrained, a third may have to adjust to amply available foreign resources from raw material exports or foreign aid. The possibility of building such stylized facts into a CGE model and drawing quantitative implications about how they influence the economy can be provide policy insight. On the other hand, CGE models are stupid.

They do what their closures tell them to do, and can easily generate economically implausible results. Navigating between informed understanding of the economy in question and dealing with the recalcitrance of the models is a constant challenge for any applied CGE economist.

Both Johansen and Chenery no doubt believed that their models would be employed by dedicated national and regional planning offices to help them guide sectoral and macroeconomic strtuctural change. Ironically, in practice CGE modeling has come to be used for adversarial purposes, for example by the World Bank and International Monetary Fund to advocate their Washington consensus policies and on all sides of the debates about the North American Free Trade Agreement and the Doha round of WTO negotiations. How a model is closed enters centrally into this arena, because its closure can to an extent be rigged to make it generate the qualitative results that the modeler thinks it should.

Finally, the models are useful insofar as they can execute quantitative thought experiments, e.g. which ”effects” will dominate responses under what sets of circumstances? In policy practice it may well turn out that the economy will be responding to forces that the model-builder did not contemplate (I can’t imagine that in 2006 US policy-makers were computer-gaming events such as those that occurred in 2007-2009). This lack of relevance is not a weakness of the methodology per se, but it suggests a degree of humility is appropriate for model-builders in the face of Keynes’s “dark forces of time and ignorance which envelop our future.”

In this paper I will argue informally along these lines, beginning with the history of developing country CGE models, going on to specification and closure, and finally describing a few models with financial extensions. Sectoral detail is central to CGE analysis, but most of the discussion focuses on the models' patterns of macroeconomic causality, because that strongly influences their sectoral results. For a more complete review of the history, see Mitra-Khan (2008).

Early CGE models in development economics

To begin with Chenery, he was a student of Wassily Leontief at Harvard and a pioneer in using input-output analysis for development planning. He taught at Stanford in the 1950s, with Kenneth Arrow and Hendrik Houthakker among his colleagues. From Houthakker he acquired an interest in complete systems of demand equations (as did Johansen from Ragnar Frisch). Arrow of course had made general equilibrium into a major concern of the day.

Chenery combined these ideas by extending the closed Leontief model to incorporate supply restrictions on labor and/or capital. With Hirofumi Uzawa (1958) he solved demonstration multisectoral models following an essentially Keynesian specification that Arrow and Hahn (1971) later called a "Leontief economy." The solution algorithm rested on Keynesian demand, price-cost, and distributive relationships. As will be seen, it provides a useful means to think about how CGE models function. A quick sketch goes as follows.

For any *n*-dimensional column vector X, let X' be its transpose and $\hat{X}$ be the $n \times n$ matrix with the elements of X along the main diagonal and zeroes elsewhere. Let A be an input-output matrix and $\theta_i = 1 - \sum_j a_{ji} > 0$. If X_i is gross output in sector i then

$V_i = \theta_i X_i$ is its real value added (for simplicity assume that the input-output coefficients a_{ij} are all constant).

Let P' be a row vector of prices of goods and services by sector, and Q' be a vector of prices of value-added. Then the price system is set by the equation

$$P'(I - A) = Q'\hat{\theta}$$

or

$$P' = Q'\hat{\theta}(I - A)^{-1} \quad .$$

(1)

Johansen called $P'(I - A)$ a vector of "net prices" which is equal to $Q'\hat{\theta}$ or the vector of values of value-added by sector.

For simplicity, assume that there are only two primary inputs into production which can be shifted across sectors – "labor" and "capital" with a wage w and profit rate r. In sector i it will be true that

$$Q_i V_i = wL_i + rK_i$$

with L_i and K_i as the quantities of labor and capital used in production.

Johansen and Chenery worked with sectoral neoclassical production functions but it is more straightforward to work with cost functions instead. Under constant returns to scale, in each sector the price of value added is set by a linear homogeneous function.

$$Q_i = \Gamma_i(w, r) \quad .$$

(2)

Shephard's Lemma then gives primary input ratios as

$$L_i/V_i = \partial\Gamma_i/\partial w \qquad \text{and} \qquad K_i/V_i = \partial\Gamma_i/\partial r \quad .$$

(3)

In words, the factor prices w and r determine labor and capital use by sector in (3), prices of value-added in (2), and commodity prices from (1). These relationships constitute the initial step of a Chenery-Uzawa solution algorithm for a CGE model. Because labor costs make up most of value-added it is natural to fix the money wage w to scale the price system in (1) and (2). From a Walrasian perspective the wage becomes the numeraire, but this interpretation elides the fact the fact that the money wage (along with interest and exchange rates) is a pivotal "macro price," with repercussions all across the macro system.

A second step brings in the demand side. If we ignore effects of the income distribution on demand (an omission remedied below), then we can define income Y as the value of GDP,

$$Y = Q'V = Q'\hat{\theta}X$$

in which V is a column vector of levels of real value-added by sector.

The usual Keynesian stability condition for a demand-driven macro system asserts that there has to be a saving "leakage" from income. To see how such a condition can be satisfied, assume the value of consumption in sector i is given by $P_iC_i = \chi_i[P', (1-s)Y]$ with the spending levels χ_i coming from a complete set of demand equations so that $\sum P_iC_i = \sum \chi_i = (1-s)Y$ with s as the overall saving rate. If β is a vector of the sectoral shares of consumption spending in disposable income ($\beta_i = P_iC_i/Y$) then the vector C of real consumption flows is given by

$$C = \hat{P}^{-1}\beta Y = \hat{P}^{-1}\beta Q'\hat{\theta}X$$

The elements of the column vector $\hat{P}^{-1}\beta$ will sum to less than one, so that the stability condition will be satisfied. Dimensionally, $\hat{P}^{-1}\beta$ is $n \times 1$ and $Q'\hat{\theta}$ is $1 \times n$ so that $\hat{P}^{-1}\beta Q'\hat{\theta}$ is an $n \times n$ singular matrix.

Now bring in the Leontief closed model for output determination. If F is a vector of final demand levels besides consumption (investment, government purchases, exports) then the input-output balance is

$$X = AX + C + F$$

which solves as

$$X = (I - A - \hat{P}^{-1}\beta Q'\hat{\theta})^{-1}F \qquad .$$

(4)

Sectoral levels of real value-added are

$$V = \hat{\theta}X \qquad .$$

Equation (4) constitutes the second stage of the Chenery-Uzawa algorithm, giving the pattern of production generated by the factor prices and levels of final demand.

In a third stage, one could consider iterating on r (or the wage-rental ratio w/r) to bring demands for labor and capital into equality with pre-specified levels of supply. (If the market for one primary input clears then so will the market for the other by Walras's Law.) Note that the *real* wage or profit rate is involved in this scenario – how that might be influenced by policy is left unclear. Also, the iteration procedure may not converge if there are destabilizing "perverse" income effects in demand (see below).

In the age of mechanical desk calculators, slide rules, and rudimentary computers this procedure for solving small CGE models numerically turned out to be effective for systems with a few sectors, since it needed only matrix inversions to solve for the price vector and the closed Leontief demand equations after each iteration on the input price levels.

Chenery worked with demonstration models – the first attempts at applied systems for developing countries came a decade or so later. These efforts were of course strongly influenced by Johansen's truly applicable model for Norway, published in 1960.

Johansen and CGE development models

As Chenery's algorithm exemplified, a lot of effort 50 years ago was devoted to figuring out how to solve nonlinear models. In his multi-sectoral growth (MSG) model Johansen sidestepped that issue with his log-linearization methodology in a planning context. He also sidestepped issues about model closure to be discussed below.

I got involved in Chenery's modeling efforts as a graduate student in his shop at Harvard. After I got my Ph.D. I worked in the Chilean planning office in Santiago as some sort of an "advisor" between 1968 and 1970. I doubt that I did much good for Chile's economy but learned a little bit about it. One issue heavily debated at the time was over the impacts of trade liberalization. It seemed natural to solve a CGE model in which domestic traded goods prices were determined by relationships such as

$$P_i = e(1 + t_i)Z_i^* \tag{5}$$

for sector i with P_i as its price level, t_i its tariff rate, Z_i^*an index of border prices for the sector in question, and *e* the exchange rate. The t_i could be manipulated to trace through the effects of changes in trade policy.

I visited my wife's family in Sweden after Chile, and took the occasion to go to Oslo to discuss this idea with Leif. As I recall, he was not enthusiastic about inserting a standard trade theory assumption such as (5) into his planning model but still thought I should go ahead. Back in the US and teaching at Harvard I gave it a try. The result was the model by Taylor and Black (1974), solved in early 1971 using Johansen's log-linearization approach and published a few years later.

Chenery at the World Bank

Chenery moved the World Bank in 1972 as vice-president for development policy. He set up an active research group, directed by John Duloy, which put a lot of effort into developing CGE models. Under Robert McNamara's presidency the Bank became concerned with poverty alleviation (a preoccupation that persists to this day) which led to attempts to "model" poverty in a CGE framework. Two independent, parallel efforts led to models of South Korea by Irma Adelman and Sherman Robinson (1978) and Brazil by Frank Lysy and me (1980). (Publication of the Lysy-Taylor model was held up for more than a year by Alan Walters, then a high level Bank bureaucrat and later a key advisor to Margaret Thatcher, because it incorporated saving rates differentiated by sources of income, as illustrated below. The distinction shows up in the data but Walters apparently found it politically unacceptable.)

The models functioned somewhat differently, with changes in internal terms of trade bearing the main burden of macro adjustment in the Korea specification, while solutions for Brazil emphasized shifts in sectoral levels of economic activity and income redistribution via forced saving (see below), a distinction which persisted through many subsequent modeling exercises.

Duloy and Chenery took the lead in setting up other projects. At least five continue to have an impact.

Social accounting matrixes as invented by Richard Stone (1966) became the accepted vehicle for describing the specification and data base for CGE models. A SAM is a matrix presentation of the combined national income and product (NIPA) and flows of funds (FOF) accounts. As such it automatically includes the Keynesian income = expenditure identity. Johansen basically used the same technique (see his Table 3.4;1 for example) but it was introduced into the Bank and its models by Stone's student Graham Pyatt, e.g. Pyatt and Round (1985).

The Korea and Brazil models were solved using versions of Chenery's old algorithm, which required some coaxing to work. Solution technology became much more routine with the GAMS package for organizing data in SAM form and solving large nonlinear programming models based on the matrixes. GAMS started out as Bank project led by Alex Meeraus. It was privatized in 1987, and is widely used.

Alan Powell, an Australian like Duloy, began the development of the Johansen-style model now called ORANI which has been applied in Australia and elsewhere (Peter Dixon has also been a major contributor). One of the spin-offs is the flourishing GTAP project for analyzing the effects of changes in trade policy. Another is the GEMPACK program that extrapolates from the Johansen log-linear approximation to a CGE model to get a full solution in levels of flow variables.

After Korea, Sherman Robinson and various co-authors went on to construct a whole string of models, mostly applied in developing countries.

Finally, in trying to understand how our model worked, Lysy and I came up with the notion that the same basic model can support distinct closures with qualitatively different outcomes. The idea was controversial when first presented at a World Bank conference in 1978 and seems to remain so in 2010.

Later developments

As my little dust up with Alan Walters exemplifies, politics has always been part of the CGE world, not least in the World Bank which after all is based in Washington DC. By the time Chenery left the Bank in 1982, its use of CGE models had been built in. He was succeeded by Anne Krueger, who redirected the research program to focus on trade liberalization and other forms of deregulation. The models were utilized to make much of her case. The change was in line with the election of Ronald Reagan and the emerging Washington consensus about development policy.

I would argue that some of the Bank's modeling work went beyond research into design of packages aimed to sell the purported benefits of liberalization but I'll leave that judgment to others. In any case, planning was replaced by an emphasis on the virtues of deregulating a Walrasian economy; Johansen's Nordic communism and Chenery's American liberal Democratic leanings were transformed into a hardline Reagan Republican approach to economic policy.

At the rhetorical level, replacing the word "planning" with "structural reform" (a code phrase for deregulation) took the form of conflating the line of work described heretofore with “applied general equilibrium” (AGE) models. They grew out of the invention by Herbert Scarf (1967) of an algorithm similar to the simplex method of linear programming (another hot topic at the time) to *approximate* the equilibrium price vector in an Arrow-Debreu general equilibrium system. In effect the algorithm applied the simplex method to a grid which could be tightened around a fixed point of a mapping of the price system into itself. From a constructive point of view, however, true convergence of the algorithm to a fixed point has not been proved.

Models solved with the Scarf algorithm and designed to address policy questions began to appear in the early 1970s, e.g. Shoven and Whalley (1972). At first they were written up as applications of pure general equilibrium theory but that emphasis gradually faded into the 1980s. The key rhetorical move was to graft the invocation of general equilibrium onto modeling along Johansen’s lines, based on consistent Keynesian accounting. Presentations of models from the Bank and elsewhere started out from micro foundations in utility and production functions, often threw in a paragraph or two about how the work was based on Arrow-Debreu, and then slipped in macroeconomics via a balanced SAM consistent with the micro. This structure of the papers led almost automatically into analyses of the welfare benefits of eliminating “distortions” in a Walrasian system.

Over almost 30 years that emphasis has not changed. But at best the models “…can be considered as ad hoc numerical exercises, seeking consistency and balance in accounts. Nothing more – especially nothing in [general equilibrium] theoretical anchors of any sort – is warranted.” (Vellupilla and Zambelli, 2010, p. 23)

Leif was a world class economic theorist and certainly knew about Arrow, Debreu, Walras, and general equilibrium. Of these three authors, only Arrow gets a couple of passing references in the book about the MSG model. Rather more attention is paid to planning models developed for Italy by Chenery in 1953, the Netherlands central planning bureau a few years later, and by Frisch. Johansen's model emphasized macroeconomic balancing across sectors in a growing economy. This approach had vanished from most of the CGE literature two decades or so after his model was first presented. A few other research ideas, however, did emerge.

The models of trade liberalization faced, and to a large extent skirted around, some minor technical hurdles, discussed below.

Another small technical advance was to set up SAMs with flow accounting combining data from NIPA and FOF sources, and then extend the financial flows over time (along with capital gains) into changes in balance sheets set out in a financial accounting matrix or FAM. One could then investigate how a real/financial equilibrium would respond to perturbations. An early paper in the CGE world was by Rosensweig and Taylor (1990).

After the 1980s not much happened by way of novel model design apart from using GAMS and GEMPACK to solve ever larger systems, getting into the million-variable range. How one can understand what is going on with a million variables is a mystery to me, but perhaps the large teams now working on the models can do so.

One final historical observation is that independently of CGE and AGE efforts still another research tradition grew up around macroeconomic accounting with “no black holes.” It was led by Wynne Godley, initially in the UK Treasury, then at the Department of Applied Economics at Cambridge (directed by Stone when Johansen completed work on his model there in 1958-59), and later in other places. In the preface to a recent publication, Godley and Lavoie (2007), he recalls that in early 1974 “I first apprehended the strategic importance of the accounting identity which says that, *measured at current prices,* the government’s budget deficit less the current account deficit is equal, by definition, to private saving minus investment” (p. xxxvi, emphasis in original). Another way to say the same thing is that after the raw data have been massaged (or cooked, or mangled) to fit into a NIPA/FOF/FAM accounting scheme, the numbers satisfy macroeconomic balances extensively discussed below. To repeat the point made earlier, macro equilibrium is built into the basic information that modelers use.

Macro accounting

Godley’s identity is a natural consequence of SAM/CGE accounting. To work out its implications, we can begin with a condensed version of the Chenery-Uzawa model sketched above. Table 1 is a SAM for a one-sector open economy. It presents flow variables in extensive or level form and nominal terms (a price index multiplied by a volume index). There are three accounting conventions in a SAM: all entries in a row (but not a column) are valued at the same price; sums of corresponding rows and columns are equal; and in flows of funds rows, sources of funds are given a positive sign, and uses are negative. The one-sector SAM contains the macroeconomic essentials of its multisectoral cousins used by Johansen and Chenery.

Table 1

The first column summarizes how income is generated from production. The first row shows values of the various components of output. The flow entry aPX (*a* is an input-output coefficient, *P* is an overall price index, and *X* is output) in the upper left-hand cell enters into both costs and the value of output. The other components of demand are real consumption *C,* government spending *G,* exports *E,* and investment *I.*

Dividing the entries in the first column by *X* gives a decomposition of *P* in terms of cost,

$$P(1 - a - \pi) = w\lambda + eZ^{*}m$$

(6)

with π as the share of profits in total output. The money wage is *w* and λ the labor-output ratio. The spot exchange rate is *e,* Z^{*} the border price of imports, and *m* an import/output coefficient. (Imports are treated as a component of cost since in the first instance they are purchased by business).

Analogously to equation (1), *P* can be expressed as a mark-up on labor and import costs,

$$P = (w\lambda + eZ^{*}m)(1 - a - \pi)^{-1} \quad .$$

(7)

Total profits can also be written as $\pi PX = rPK$ with *r* as the profit rate on the existing capital stock *K* (valued at the general price index *P*), implying that (6) can be rewritten as

$$P(1 - a - ru^{-1}) = w\lambda + eZ^{*}m$$

(8)

in which $u = X/K$ stands for utilization of capital.

Dividing both sides by *P* gives another version,

$$1 - a - ru^{-1} = \omega\lambda + (\frac{eZ^*}{P})m$$

(9)

with $\omega = w/P$ as the real product wage. For a fixed value of *u,* this equation gives the familiar inverse trade-off between the profit rate and the real wage. From the demand side, however, an increase in ω may cause *u* to go up enough to allow *r* to rise (such responses have been observed in practice in "wage-led" economies). Shifts in the exchange rate *e* would add a third distributive dimension, between the home country and the rest of the world. The real impact of a nominal devaluation would depend on the responsiveness of P to *e*, along with intersectoral rebalancing.

In the second row of Table 1, households are getting income from wages as well as interest at rate i on debt ("bonds") issued respectively by the corporate sector (B_C) and government (B_G). Assume that taxes *T* and household saving S_H are proportional to income, $T = tY_H$ and $S_H = s_h Y_H$. Plugging these relationships into the second column, dividing through the first row by *P,* and a bit of grinding gives an expression similar to (4) for output,

$$X = [1 - a - (1 - s_H - t)\omega\lambda]^{-1}[(G + E + I) + (1 - s_H - t)i(B_C + B_P)/P] \quad .$$

(10)

This equation is a one-sector version/extension of the closed Leontief model. For given values of the real wage and price level, it determines *X* for pre-determined levels of demand injections *G, E,* and *I* along with consumption supported by interest payments on real debt $(1 - s_H - t)i(B_C + B_P)/P$. With the price system naturally scaled to the money wage *w* (and exchange rate e) as in (7), then iteration on the profit rate or real wage could in principle be used to bring labor demand λX into line with a pre-determined supply. Whether the market would replicate such an algorithm is an altogether different question.

Distributive and demand relationships

The foregoing discussion can be extended a step further, along the lines of the model that Keynes sketched in chapter 19 of the *General Theory* (1936).

The accounting appears in Table 2, based on Table 1 with the foreign sector and disaggregated flows of funds omitted. It is set up with variables in real terms (all entries in the first table divided by the price index) and intensive form (a volume index divided by the capital stock). For simplicity total transfers νPK of interest (and dividends) from the corporate to household sector are assumed to be proportional to the capital stock.

Table 2

As before, the money wage anchors the price system. Keynes of course argued *against* the ability of money wage cuts to stimulate employment. The reasoning goes through in a model with one sector, but maybe not when it has more than one. In a one-sector constant returns to scale (CRS) economy with a neoclassical or mark-up cost function and with labor and "capital" as the only inputs, cutting the money wage will reduce the price level in proportion, leaving the real wage unchanged. Consequently the level of employment will not change.

Mostly to disarm the opposition, in the *General Theory* Keynes assumed that there would be decreasing returns to the use of labor in production and that the real wage would be equal to its marginal product (he had shown scant inclination toward either notion in earlier work, or in later work for that matter). Keynes's argument does *not* rely on these assumptions. One reason to include them is that they are built into most applied CGE exercises.

As in (2) and (3), a neoclassical cost function takes the form

$P = \Gamma(w, rP)$ or $1 = \Gamma(\omega, r)$.

(11)

Shephard's Lemma states that

$\lambda = \partial\Gamma/\partial w$ and $u^{-1} = \partial\Gamma/\partial(rP)$.

(12)

These equations can be solved for λ, ω, and *r* as functions of *u*. As usual in this calculus, *u* and ω will be related inversely because of decreasing returns to labor when capital is fixed (Keynes called this relationship the first classical postulate). As above, the capital share is $\pi = ru$. Because the labor share is $\psi = 1 - \pi$ the functional income distribution is determined by *u* as well. If we concentrate on the profit share we get a *distributive equation*

$\pi = \pi(u)$.

(13)

With the real wage and profit share set by *u*, any increase in the nominal wage *w* would have to be met by a proportional increase in *P.* This was the gist of Keynes's argument against cutting money wages – they will just bid down the price level and leave real wages unchanged.

The obvious question is how *u* gets determined. The answer is through the principle of effective demand with distributive effects built in. To see the details, let $c = C/K$ and $g = I/K$ be consumption and investment per unit of capital respectively.

An investment function (based on ideas of Michal Kalecki,1954, and Josef Steindl, 1952) could take the form

$$g^I = g_0 + \alpha r + \beta u = g_0 + (\alpha\pi + \beta)u = g^I(\pi, u) \quad . \tag{14}$$

The βu term is a simple version of the accelerator, and αr reflects profitability.

Sources of saving are from household income and profits. The flow of funds row shows that total saving is $s_H(u + v) + (s_C - s_H)r$ and the macro balance condition becomes

$$g^I - s_H(u + v) + (s_C - s_H)\pi u = 0 \quad . \tag{15}$$

This expression is a *demand equation*

$$u = u(\pi) \quad . \tag{16}$$

Solving the demand and distribution equations together gives macro equilibrium levels of *u* and π (along the with real wage, labor share, employment $L = \lambda u K$, etc.).

The closed Leontief model is a multisectoral generalization of this system. Expanding the Chenery model, one can build in a vector of sectoral investment functions “by destination” along the lines of (14), which when multiplied by a “B” matrix will generate investment demands “by origin” for sectors that produce capital goods. The investment functions and a system of complete demand generate a set of sectoral demand-supply balances which can be solved as in (4) or (10) for output levels with the A matrix taking care of intermediate flows.

The nature of a multisectoral distribution function depends on assumptions about whether or not capital can move between sectors in the short run. If not, then profit rates at the sectoral level will follow from relationships such as the second equation in (12). If so, profit rates will presumably equalize (or at least be proportional) across sectors. Either way, sectoral prices will be proportional to the nominal wage (and exchange rate) for a given output vector. Keynes's emphasis on cost-driven prices applies in many sectors as well as in just one.

Whether cutting money wages will create employment is less clear. A shift in w will change relative prices across sectors and may alter input coefficients. If, say, a wage increase raises demand for labor-intensive goods via the complete system of demand equations, then overall labor demand could (perversely) go up as well. Such income effects on demand composition can't show up in a one-sector model. They can be crucial in developing countries. Argentina's historical reliance on the wage good, beef, as a key export was an important historical example (Chichilnisky and Taylor, 1980).

Macro balance conditions

Now we can get back to the macro balance condition that Godley apprehended. (One might add that Steindl had the same revelation in Vienna in the early 1980s.) The FOF rows in Table 1 show how saving from different sources of income gets channeled through the financial system.

Total household saving S_H is used to acquire new debt $\dot{B}$ issued by corporate actors and the government (the "dot" over total debt *B* signifies a change per unit time). Corporate saving S_C and new debt $\dot{B}_C$ are used to finance the value of investment PI. The parentheses mean that government saving S_G is, as usual, negative. The fiscal deficit is financed by new domestic ($\dot{B}_G$) and foreign ($e\dot{\Delta}^*$) borrowing. "Foreign saving" S_F can be seen to be equal to the trade deficit $eP^*M^* - PE$ which on capital account generates net lending $e\dot{\Delta}^*$to the home country. A question of causality immediately arises – does the rest of world set the capital inflow $e\dot{\Delta}^*$ or does it allow the home country to choose its own trade deficit? For developing economies, the former situation arises at least as often as not.

In any case, it is easy to see that the sum of the four FOF rows is

$$S_H + S_C + S_G + S_F - PI = 0$$

(17)

so that Keynes's overall macro balance condition is satisfied. One implication is that only three of the four FOF balances can be independent. If financial flows for corporates, the government, and the rest of world are determined independently, then the household balance $S_H - \dot{B} = 0$ will be satisfied automatically.

Let private saving be $S_P = S_H + S_G$. Then substitution among (17) and entries in Table 1 gives

$$(PI - S_P) + (PG - T) + (PE - eP^*M^*) = 0 \quad .$$

(18)

This equation is the Godley-Steindl macro balance. Each term in parentheses is the net borrowing of a sector, and the sum of all sectoral net borrowing flows must be equal to zero.

Model closure

The balance can be interpreted in several ways. For example, in the largely Keynesian approach that has been the focus heretofore, a price-cost relationship such as (7) and the distributive and demand equations (13) and (16) determine macro equilibrium. On the demand side, if "leakages" S_P, T, and $eP^*M^*$are all proportional to (or more general functions of) output and the injections *PG, PE,* and *PI* are at least partially independent of *X*, then (18) can be solved in standard multiplier fashion for total economic activity.

In a Keynesian or Marxist model, the "supply side" is represented by a distributive relationship such as (13). Orthodox CGE models, on the other hand, dispense with effective demand and assume that supply relationships determine output as well as distribution. In practice they set *X* by an assumption of full employment of labor, capital, and other inputs. In other words, Say's Law rules. How does this specification enter into (18)? There are several possible answers.

In his MSG model Johansen assumed full employment, thus determining S_P and eZ^*M^* as functions of *X*. The real injection levels *G, E,* and *I* were set exogenously. He worked with neoclassical production functions and marginal productivity conditions, thereby implicitly including cost functions determining price levels as mark-ups on the wage. To satisfy (18) he assumed that the tax level *T* (or direct taxes in particular) would be determined endogenously to ratify full employment. James Meade (1961) took a similar tack by endogenizing real government spending.

A more traditional specification of closure shows up in many World Bank models (Taylor and Arnim, 2006). In Table 1, the sum of the FOF rows for households and corporates gives the balance $S_P - PI - \dot{B}_G = 0$ for the overall private sector. It says that private saving is used to finance investment and purchases of newly issued government bonds. Bank models tend to freeze the level of fiscal borrowing $\dot{B}_G$ and fix private saving by postulating full employment. The consequence is that investment *PI* must be endogenous as in neoclassical growth models. The models also treat the foreign deficit $e\dot{\Delta}^*$ as pre-determined. If government spending *G* is set by policy, the only remaining free variable is *T*. Direct taxes have to adjust endogenously to assure macroeconomic balance.

As assessed in detail below, these assumptions are peculiar, especially for developing countries. They do not have typically enjoy full employment and adept fiscal programming is rarely observed. We have already seen that there are other ways in which economies arrive at macroeconomic balance, and a few more can be mentioned.

One is another variant around Say's Law. Suppose that as with Johansen output is set by full employment, all three real injections are fixed, and saving, taxes, and imports are proportional to output. How can (18) be satisfied? One answer can be constructed around the price-cost relationship (7), the distributive relationship (9), and the investment-saving balance (15). The latter shows that with *u* held constant by Say's Law an increase in investment g^Icould be met by saving generated from a higher profit share π if the corporate saving rate s_C exceeds the household rate s_H.In (9), again with

u held constant, $ru^{-1} = \pi$ so that the higher profit share would have to be met by a lower real wage ω. Finally, (7) shows that with a constant money wage *w,* the reduction in the real wage would occur through a jump in the price level *P.*

This mechanism is called forced saving, because consumers with low saving rates (high consumption rates) are "forced" to consume less by rising prices. It has been commonplace in developing countries, both in times of supply strangulation caused by a drop in external finance $e\dot{\Delta}^*$ which provokes faster inflation to restrain demand and (running in reverse) when inflation is stopped by government fiat (often accompanied by creation of a new currency and attempts to remove inflation indexation from contracts) in "heterodox shock" stabilization programs, usually setting off a surge in demand.

Another possible outcome is that a reduction in *P* may be induced by tight money. From the equation of exchange

$$HV = PX \quad . \tag{19}$$

CGE modelers often interpret (19) as constituting a numeraire – under a full employment assumption the money supply H sets the overall price level P, and that's that. If "velocity" *V* is relatively stable, then presumably a reduction in *H* must be met by some combination of lower prices and lower output. The former could occur through the cost function by a reduction in the money wage *w* (if that is institutionally feasible – with the Baltic countries, Greece, and Ireland providing "interesting" test cases in 2010-11). Fiscal contraction and/or redistribution toward profits could underlie the latter alternative. Another contributing factor could be "debt deflation" in which a lower price level induces an increase in the real burden of nominal debt. Or if the debt is denominated in foreign currency, then devaluation can dramatically cut into effective demand (forced saving mechanisms can come into play as well).

The bottom line, perhaps, is that many distributive channels can influence output levels – Say's Law is not a good description of how developing country macroeconomics operates despite the fact that it is built into many CGE models.

Keynes and closure

The idea that the way macro models behave can be influenced by the causal schemes imposed upon their accounting was implicit for a long time. The foregoing discussion in some ways recapitulates in reverse the evolution of Keynes's own macroeconomics. In the *Tract on Monetary Reform* (1923), Milton Friedman's favorite among his books, he accepted the quantity theory of price determination based on (19) but was also concerned with distributive issues of the sort just discussed. In the *Treatise on Money* (1930) he worked with forced saving macro adjustment. Only in the *General Theory* (1936) did he switch to output adjustment, then came back toward inflationary forced saving in *How to Pay for the War* (1940).

In the academic literature, Kaldor (1956) was among the first to point out that there are several macroeconomic theories of distribution with different implications for how the system behaves. He then proceeded to build forced saving into several versions of a growth model *circa* 1960. Sen (1963) picked up on the idea and described several different closures. It was (independently) restated for CGE models by Taylor and Lysy (1978). Rattsø (1982) provides a helpful summary in light of the MSG model.

Accounting for trade

As already observed much CGE work growing out of Anne Krueger's palace coup at the World Bank concentrated on trade liberalization. It will be argued below that the trade models are concerned with issues that were at the forefront of open economy macroeconomics five or six decades ago but which lost importance as capital markets were liberalized. In other words they are anachronisms. Before dealing with that issue, however, some technical questions should be addressed, beginning with accounting.

Following a format invented by Godley the SAM in Table 3 shows flows in a two-country world, "home" and "foreign" or "RoW" (rest of the world, signaled by an asterisk). One key variable is the spot exchange rate e. To see how it enters we can begin in the row for "Supply" (explained further below) in the RoW. In the foreign country's own price system the value of exports is Z^*E^*in the "Export" column with price Z^* and volume E^*. In an accounting trick exports are flipped to a negative value $-Z^*E^*$in the "Home imports" row. This quantity then "crosses the border" to the home country after multiplication by $-e$ in the "Exchange rate" column, giving a landed import value in home prices of eZ^*E^* in the "Armington" column (also explained below). Adding on a tariff at rate *t* gives a final import value of $e(1+t)Z^*E^*$, consistent with the right-hand side of equation (1). To avoid bringing in government accounts the tariff proceeds teZ^*E^* are assumed to be paid directly to the private sector in the "Private" row. Private income *Y* thereby comprises the remitted tariffs plus value-added Q*V* with a price *Q* (think of a GDP deflator) and real level *V* as introduced above. At the cost of more detail, one could also include trade and transport margins in import price determination.

Table 3

The exchange rate can be seen as scaling one country's prices in terms of the others. Home exports are worth ZE/e abroad and capital flows $\dot{\Delta}^*$originating in RoW are equal to $e\dot{\Delta}^*$in the home country. Trade balances for the two economies do not enter explicitly into this accounting. But by substitution through the balanced SAM it is easy to show that

$$eZ^*E^* - ZE = e\dot{\Delta}^* \quad .$$

(20)

This relationship is a consequence of separate decisions about levels of trade and capital flows in both countries and will be useful in discussing macroeconomics below. But it has no independent standing of its own.

Just to finish explaining Table 3, the value of home output is *PX* (P^*X^* in RoW). In the second ("Arm.") column, it enters together with the value of imports $(1+t)eZ^*E^*$ into an "Armington" aggregate product with value *ZA* (price *Z* and level *A* with details below). The cost of *PX* is value-added *QV* plus domestic intermediate inputs *ZaX* with price *Z.*

The aggregate is used to satisfy all forms of demand (including home's exports) in the "Supply" row. The FOF row corresponds to the vertical sum of the disaggregated rows in Table 1, and we've already discussed the role of the exchange rate.

Technical glitches

When CGE trade models began to be solved, a couple of technical glitches soon appeared. One was that in a CRS system subject to Say's Law with "many" (*m*) potentially producing sectors and “few” (*f*) factors of production, a county should specialize in what it does best – export goods from only $f < m$ sectors in which the domestic price is determined by its corresponding border price as in equation (1) and shut down the others in which cost-based prices P_i would exceed $e(1 + t_i)Z_i^*$.

One way to get around this problem is to assume that there is a “specific” factor of production in each sector, with a return (say q_i) that can adjust in the cost function to permit the price P_i to be determined from (1). If the quantity of the fixed factor is v_i then in each sector value-added *QV* would be the sum of payments to capital and labor plus $q_i v_i$.

Another approach, followed by Taylor and Black (1974), is to assume that labor is the only variable input in the short run, subject to decreasing returns to scale. If a sector has a neoclassical CRS production function but its capital stock cannot shift to other sectors, then its profit rate r_i can play the same role as q_i.

Armington

A somewhat related issue is that in standard data presentations at the 2- or 3-digit level of classification, a sector will typically produce, export, and import the “same” good. A model should be able to rationalize this observation. Table 3 is a simple illustration of the most commonly adopted approach, invented by Paul Armington (1969) of the IMF. The basic idea is that foreign exports $E^*$are “competitive” with home output *X*, but that the two goods are imperfect substitutes. Similarly, home exports *E* trade off with output X^* in the rest of the world.

The technical trick as sketched here (the algebra can easily be made much more complicated!) is to assume that in the home country imports and domestic output enter into the "aggregate" product mentioned above,

$$A = \alpha(X, E^*) \tag{21}$$

which is then used to satisfy all local demands (including exports). A similar aggregate A^* appears in RoW.

The aggregate will have a corresponding price

$$Z = \zeta[P, (1 + t)eZ^*] \tag{22}$$

with *P* as the domestic output price, determined in standard fashion by the cost structure in the first column of Table 3.

By Shephard's lemma under the usual neoclassical assumptions we have that

$$X/A = \partial\zeta/\partial P \quad \text{and} \quad E^*/A = \partial\zeta/\partial[(1 + t)eZ^*] \quad . \tag{23}$$

According to Armington theory, reducing the tariff or appreciating the exchange rate will make foreign goods cheaper relative to home goods, thereby shifting the composition of the aggregate *A* toward E^*. There will be further repercussions through the system. The results will depend on how CGE macroeconomics is closed, as discussed below.

Note also that (22) linking the prices *Z, P,* and $e(1 + t)Z^*$ replaces (1). There is no longer a proportional tie between domestic and foreign prices. The introduction of *Z* (or Z_i for sector i) adds a degree of freedom which, again depending on the specifics of the model at hand, can help avoid the over-determination problem mentioned above.

The Armington specification does allow a country in a model to produce, import, and export products of the same sector. But it has numerous drawbacks as well (Stanford, 1992). The idea that there is *national* product differentiation ignores the fact that characteristics of manufactured goods at least are determined by firms, not countries.

This observation is particularly telling for industrial sectors in many developing countries which nowadays to a large extent are made up of subsidiaries of transnational companies undertaking assembly operations for export. The price elasticities used in applying the Armington equations are irrelevant for a transnational making multiple transactions among subsidiaries of itself.

The specification also grants a degree of monopoly power in trade to any economy because its exports of some category of goods are imperfect substitutes for goods in the same category from elsewhere. Consider imports. In a rich country, low wage, unskilled, labor-intensive imports cannot fully displace similar goods produced at a higher wage at home. Firms in a poor country cannot fully replace local products in a capital goods sector with high tech, capital-intensive machinery from abroad because the Armington equations won't let them. Such limited responses can certainly occur because of local institutional rigidities but the Armington worldview has nothing to do with that. It may have more relevance for service exports such as tourism (only Egypt has Luxor on offer, for example) but they constitute a fairly small share of total world trade.

Increasing returns

After the emergence of the new trade theory in the 1970s and 1980s, CGE modelers unsurprisingly started to incorporate its ideas into their models. Increasing returns to scale (IRS) showed up frequently. The models ignored the destabilizing effects of increasing returns that had concerned non-neoclassical economists such as Piero Sraffa (1926), Allyn Young (1928), and Kaldor (1972). They stressed how cumulative processes and imbalances, not mutual benefits and balance, could easily emerge in IRS situations. In developing countries in particular, Albert Hirschman (1958) emphasized how planners had to cope with the instabilities inherent in decreasing costs.

New trade theory amounted to clever techniques to generate interior solutions in the non-convex decision spaces created by IRS. The best-known is the Dixit and Stiglitz (1977) trick of combining a consumer taste for product variety with scale economies strictly internal to the firm to generate an equilibrium in which countries do not specialize. The technique has been incorporated into CGE computer programming packages, as an alternative to Armington. It does generate numbers, but ignores the destabilizing forces that would arise if scale economies were not all internal, and if consumers did not seek product variety. Patterns of specialization could then be much less benign than Dixit and Stiglitz suggest in their title about "…optimum product diversity…" Traditional CRS trade theorists Jagdish Bhagwati and T.N. Srinivasan (1983, p. 95) snarkily remark that these models "… are based on several special assumptions which lead to neat results but whose robustness is limited."

Although Canada is not quite a developing country (but see below) a model originating there a couple of decades before new trade theory also took on increasing returns. Stefan Stykolt and Harry Eastman (1960) proposed an argument with three premises: (1) a tariff on competing imports allows colluding local oligopolists to maintain high prices; (2) the resulting rents attract new entrants; (3) output per firm is forced downward which under IRS pushes up costs. The implication is that cutting tariffs will force firms to exit, thereby reducing costs.

In the world of models Tim Hazledine (1990) set up a CGE system to test the argument. He worked with a simple specification of increasing returns, an oligopoly mark-up function assumed to be sensitive to import competition, and an entry function depending on the price/cost ratio. With plausible parameters regarding the response of cost to IRS and the strength of the entry response,
he found nugatory real income responses to tariff elimination.

In practice, the Stykolt-Eastman argument played a big role in a CGE tournament over the impacts of the North American “free trade” agreements – an important example of the adversarial use of the models mentioned in the introduction. Enough time has now passed to allow some assessment of their effectiveness. It was not great.

Canada was supposed to benefit from strong productivity increases and investment inflows. Neither occurred, and productivity growth stagnated. With exploitation of the Alberta oil sands (a possibility omitted from the models) the economy has reverted to its traditional role as a raw material exporter with a strong exchange rate (Stanford, 2005). In the United States, slow employment expansion and the structural trade deficit have set off revulsion against globalization in general and NAFTA in particular. Mexico was supposed to be the major beneficiary of liberalization, but its export boom toward the US was accompanied by an even greater surge in imports due in part to consistent appreciation of the peso against the dollar. During 2001-08 the growth rate was around 2% per year with a trade deficit of nearly 4% of GDP. A somewhat smaller deficit supported a growth rate exceeding 7% during 1970-81.

Macroeconomic complications

The neoclassical CGE models that predicted significant benefits from North American trade liberalization largely failed. One reason rested with their macroeconomic closure. To begin to see the details about how a Say's Law closure constrains model responses, observe that dividing the second equation in (23) by the first will give an import/output ratio, say μ in the home country and μ^* in RoW. Under the standard assumption that the Armington equations take the constant elasticity of substitution (CES) form, μ and μ^* will depend on ratios of relative prices. Substituting into the trade balance (20) gives

$$eZ^*\mu[P/e(1+t)Z^*]X - Z\mu^*[P^*/eZ]X^* = e\dot{\Delta}^* \quad .$$

(24)

The topic at hand is to analyze the effects of changes in the tariff rate *t.* To trace them through we have to discuss how (24) fits into a complete model. An immediate observation is that the equation sets up a price vs. quantity trade-off in terms of closure. There are two obvious alternatives. One would be to treat the foreign currency capital flow $\dot{\Delta}^*$ as exogenous and let the exchange rate *e* adjust to "clear" the balance of payments (more precisely, a change in *e* would have effects all across the model which would be consistent with (24)). The other would be to fix *e* and let $\dot{\Delta}^*$ adjust.

Broadly speaking, the first option represents the "elasticities" approach to the balance of payments and the second relies on shifts in "absorption". Both approaches were prominent in 1950s open economy macroeconomics. As noted above CGE modelers have recreated them. In particular, orthodox models concentrate on elasticities with an endogenous exchange rate clearing the trade account. This closure is anachronistic because even for many developing countries exchange rates are set in capital markets which adjust much more rapidly than trade.

One can visualize the accounting for a complete model (too messy to be worth setting up explicitly) as a combination of the SAMs in Tables 1, 2, and 3. The main modifications are with the accounts of the government and private sector. If we work with a consolidated private sector as in Table 2, it receives income from generation of value-added but does not get direct remittances of tariff proceeds which go to the government instead. It pays direct taxes *T* to the government. In the private sector flow of funds saving is used to finance investment and acquire new government bonds. Government income becomes $Y_G = T + teZ^*E^*$. Its flow of funds is the same as in Table 1, with negative saving financed by new domestic borrowing $\dot{B}_G$ and foreign inflows $e\dot{\Delta}^*$.

Table 4 describes two possible sets of closure rules for a model based on this accounting. One corresponds to the rules adopted in orthodox CGE models. The other is broadly Keynesian. It is not difficult to think through the effects of cutting the tariff rate *t* (numerical illustrations are available in Taylor and Arnim, 2006).

Table 4

In the standard model, the key linkage runs through the government accounts. It generates a counter-intuitive *fall* in consumption when an import tariff is reduced. The reason why is that the government is constrained to borrow constant amounts from the private sector and ROW but receives less tariff revenue after liberalization. Its only possible recourse in a Say's Law world is to raise taxes on private income to balance its flow of funds, forcing consumption to decline. In terms of the GDP deflator, private income and saving are held steady by the full employment assumption, also holding investment stable. The Armington aggregate's composition will shift toward imports. Together with the lower consumption due to higher taxes, the resulting extra supply will increase exports. To ensure that (24) continues to apply, however, the exchange rate will have to increase or depreciate, partially offsetting the gain in exports. Other macroeconomic performance indicators — employment, current account, fiscal deficit — are held constant by assumption.

Several models constructed to evaluate the effects of trade liberalization under the Doha Round of WTO negotiations purported to evaluate benefits using standard deadweight loss "little triangle" calculations. All the results were contaminated, however, by the fiscal effect just described. Under the circumstances it is difficult to take estimates of "gains" from liberalization at all seriously.

This peculiar fiscal response whereby cutting a tax *reduces* consumption demand could be relaxed by treating revenue *T* as a function of output and allowing new government borrowing $\dot{B}_G$ to be endogenous. Then cutting the tariff would have no direct income effects via the fiscal deficit on demand. To see the implications one could use a traditional elasticities model such as Dornbusch (1974) incorporating export, import, and non-traded goods but *without* the Armington apparatus. Unless there are strong income or compositional effects the elasticity of the exchange rate with respect to the tariff would lie between zero and minus one. As above, a tariff reduction would have to be associated with devaluation to satisfy (24). The landed import price would still decrease, increasing volume. Exports would have to rise to hold the trade balance constant. The effect of devaluation is to shift resources from non-traded toward traded goods production, a more plausible story than the Armington fiscal linkage.

In a Keynesian system, reducing any tax such as the import tariff will increase effective demand. Output will rise, along with direct taxes. If the government deficit increases it can be financed by more borrowing. Because of the output increase and the reduction in their price from a lower tariff imports may increase strongly. As in Mexico's case mentioned above (in which the exchange rate consistently appreciated instead of staying stable), the higher trade deficit that results may not be sustainable indefinitely.

The bottom line is that both closures give extreme results, reflecting the fact that macro models are obtuse. They do what their closures tell them to do. Because observed economic outcomes fall between closures there is every reason not to take the results of any particular model too seriously. But the range of results *may* tell you something about the possibilities at hand. As Wynne Godley and Marc Lavoie put it (2007, p. 489), "It must be emphasized that the use of different closures … does not correspond in any straightforward way to different policy regimes…. [W]hatever the institutional background, some results are being systematically achieved when any particular closure is being adopted."

Financial extensions

This observation applies with redoubled force when financial considerations are brought into the analysis. A few examples are presented here. First, though, Table 5 presents an illustrative SAM for an economy in which finance is centered solely on the banking system, still a plausible approximation in low income countries in which markets have not been created for bonds issued by the government and/or central bank.

Table 5

The SAM is a slightly modified version of the one in Table 1. The last column shows flow accounts for the consolidated banking system. It issues new loans $\dot{L}$ to firms and buys new bonds $\dot{B}$ issued by the government. (In other words government deficits not financed from abroad are "monetized"). It also may acquire foreign reserves $e\dot{R}^{*}$which follow from the equations

$$e\dot{R}^{*} = e\dot{\Gamma}^{*} - e\dot{\Delta}^{*} = e\dot{\Gamma}^{*} - S_F$$

(25)

in which $e\dot{\Gamma}^{*}$is a capital inflow to the government and S_F is the trade deficit financed by borrowing from abroad. The change in the money supply $\dot{H}$ in the last column is the sum of changes of banking system credits to the government and private sector, and international reserves.

The IMF's venerable financial programming exercises can be seen as a rudimentary CGE model based on the Table 5 SAM. Its goal is to use the equation of exchange (19) as a tool to program the fiscal deficit. A forecast of the price level *P* can be obtained from the first column of the SAM, perhaps blended with external price determination for traded goods as in (1). Output *X* is assumed to be fixed, and velocity *V* is an "institutionally determined" constant. A target level of the money supply then follows from (19).

The goal is to reduce the trade deficit S_F. If that happens, from (25) there would be an increase in international reserves, pushing up *H*. To meet this money supply target some other form of banking system assets must be reduced. If the change in loans to the private sector $\dot{L}$ responds to the needs of production then the only thing that can be cut is new lending to the government $\dot{B}$, i.e. the fiscal deficit must be cut.

Causality, in other words, is supposed to run from the fiscal deficit to the external deficit. Twin deficits do not often show up in the data and when they do causality is more likely to run from a higher trade surplus to a lower fiscal deficit (Ocampo, Rada, and Taylor, 2009). This discrepancy has not prevented the Fund from applying the model for more than five decades, most recently at the eastern end of Europe with some success in reducing trade deficits by creating recessions.

Much more interesting is a recent model for China by Jingliang Xiao (2009), built around output and monetary balances. He works with net exports *N* which should depend on the real exchange rate e/P. Investment is supposed to be an increasing function of a capital asset price $q = r/i$. Omitting government for simplicity the macro balance condition becomes

$$X = C + I(r/i) + N(e/P)$$

(26)

In a surplus labor economy like China's the real wage ω can be assumed to be fixed. Under the usual neoclassical assumptions ω and the capital stock *K* will determine output *X,* capacity utilization u, and the profit rate *r*. With consumption depending on output, then in (26) if the interest rate i is given, investment will be determined. The real exchange rate will have to adjust to make $N = X - C - I$. A key question is the extent to which adjustment in the real rate will occur through changes in the nominal rate e or the price level P. These two variables, however, are linked via cost.

With fixed values of ω, r, and u, equation (9) suggests that P itself will be a strongly increasing function of e, i.e. a substantial nominal exchange rate adjustment will be needed to offset a change in the interest rate. This sort of response is common in middle income countries. The transmission of monetary policy into inflation often runs through the exchange rate. The strong response of *P* to *e* means that in Figure 1, the "Macro balance" schedule will have a steep positive slope.

Figure 1

The flow change in the nominal money supply will be

$$\dot{H} = N + e\dot{\Gamma}^{*} + \dot{Q}$$

in which capital inflows $e\dot{\Gamma}^{*}$ could go to the government or private sector. They are assumed to depend positively on the exchange rate (a cheaper renminbi makes purchases of Chinese liabilities more attractive) and the interest rate. Monetary injections by the central bank are represented by $\dot{Q}$.

The flow increase in money demand could be expressed as $\dot{\eta} = P(e)f(i)$ with $dP/de > 0$ as discussed above and $df/di < 0$. The flow money market equilibrium condition becomes

$$P(e)f(i) = N(e/P) + e\dot{\Gamma}^{*}(e,i) + \dot{Q} \quad .$$

(27)

An increase in the exchange rate has an ambiguous effect in this equation. It increases the price level and money demand on the left-hand side but also raises money supply growth from a higher trade surplus and capital inflow on the right. A higher interest rate will reduce money demand and increase the inflow. If the money supply goes up more than demand in response to *e*, the “Money balance” will have a steep negative slope as in Figure 1.

In the Johansen-Chenery planning tradition this model can be used to analyze how China might “rebalance” by orchestrating a reduction in its trade surplus, which much of the world considers a desirable policy goal. As a warm-up we can look at the effects of increasing *C* in the Macro balance and $\dot{Q}$ in the Money balance.

To meet the level of output if consumption rises there would have to be lower exports or investment, implying a stronger (lower) exchange rate or a higher interest rate. With a steep Money balance schedule the interest rate would bear the main burden of adjustment.

If monetary injections increase, the interest rate would have to decline (raising money demand and reducing capital inflows) or the exchange would have to appreciate (reducing the trade surplus and inflows). With a steep Macro balance the interest rate would again respond strongly. However, as the diagram is drawn, offsetting macro and monetary responses of i would lead to a reduction in *e* as the principal outcome of the two changes.

A private consumption increase could be stimulated in part by tax reduction and directed incentives; public consumption could be raised as a matter of policy. Because China already has a very high investment rate, it is not clear that monetary expansion should be targeted too strongly at cutting interest rates, i.e. a smaller shift in the Money balance than shown in Figure 1 would more evenly split the adjustment burden to a lower trade surplus between i and *e.*

In any case, because of the strong pass-through of exchange rate changes into the price level, appreciation in and of itself will probably do little to affect the trade balance. Coordinated monetary and fiscal interventions would be far more helpful, and also ratify a stronger renminbi.

Final observation

Xiao's model of course permits analysis of the sectoral adjustments that would accompany the foregoing macroeconomic scenario – that is a major strength of CGE modeling. But directions of sectoral shifts are driven by changes in macro variables such as the interest rate and exchange rate. Understanding their role in the economy is a prerequisite for sensible disaggregated modeling. One may or may agree with Xiao's assumptions regarding closure, but they certainly provide a basis for intelligent policy discussion.

References

Adelman, Irma, and Sherman Robinson (1978) *Income Distribution in Developing Countries: A Case Study of Korea,* Palo Alto CA: Stanford University Press

Armington, Paul S. (1969) "A Theory of Demand for Products Distinguished by Place of Production," *IMF Staff Papers, 16*: 159-178

Arrow, Kenneth J., and F. H.Hahn (1971) *General Competitive Analysis,* San Francisco: Holden-Day

Bhagwati, Jagdish N., and T. N. Srinivasan (1983) *Lectures on International Trade,* Cambridge MA: MIT Press

Chenery, Hollis B., and Hirofumi Uzawa (1958) “Non-Linear Programming in Economic Development” in Kenneth Arrow, Leonid Hurwicz, and Hirofumi Uzawa (eds.), *Studies in Linear and Non-Linear Programming,* Palo Alto CA: Stanford Univesity Press

Chichilnisky, Graciela, and Lance Taylor (1980) “Agriculture and the Rest of the Economy: Macro Restrictions and Policy Restraints,” *American Journal of Agricultural Economics, 62*: 303-309

Dixit, Avinash K., and Joseph E. Stiglitz (1977) “Monopolistic Competition and Optimal Product Diversity,” *American Economic Review, 67* (no. 3): 297-308

Dornbusch, Rudiger (1974) ‘Tariffs and Non-Traded Goods,” *Journal of International Economics, 4*: 177-186

Godley, Wynne, and Marc Lavoie (2007) *Monetary Economics: An Integrated Approach to Credit, Money, Income, Production, and Wealth*, London, Palgrave/Macmillan

Hazledine, Tim (1990) “Why do Free Trade Gain Numbers Differ So Much? The Role of Industrial Organization in General Equilibrium,” *Canadian Journal of Economics, 23*: 791-806

Hirschman, Albert O. (1958) *The Strategy of Economic Development,* New Haven CT: Yale Universitry Press

Johansen, Leif (1960, 1974) *A Multi-Sectoral Study of Economic Growth,* Amsterdam: North-Holland

Kaldor, Nicholas (1956) "Alternative Theories of Distribution," *Review of Economic Studies, 23*: 83-100

Kaldor, Nicholas (1972) “The Irrelevance of Equilibrium Economics,” *Economic Journal, 82*: 1237-1255

Kalecki, Michal (1954) *Theory of Economic Dynamics,* London: Allen and Unwin

Keynes, John Maynard (1923) *A Tract on Monetary Reform,* London: Macmillan

Keynes, John Maynard (1930) *A Treatise on Money,* London: Macmillan

Keynes, John Maynard (1936) *The General Theory of Employment, Interest, and Money,* London: Macmillan

Keynes, John Maynard (1940) *How to Pay for the War,* London: Macmillan

Meade, James (1961) *A Neo-classical Theory of Economic Growth,* London: Allen and Unwin

Mitra-Khan, Benjamin H. (2008) “Debunking the Myths of Computable General Equilibrium Models,” New York: Schwartz Center for Economic Policy Analysis, New School for Social Research

Ocampo, José Antonio, Codrina Rada, and Lance Taylor (2009) *Growth and Policy in Developing Countries: A Structuralist Approach,* New York: Columbia University Press

Pyatt, Graham, and Jeffrey I. Round (eds., 1985) *Social Accounting Matrices: A Basis for Planning,* Washington DC: The World Bank

Rattsø, Jørn (1982) “Different Macroclosures of the Original Johansen Model and their Impact on Policy Evaluations,” *Journal of Policy Modeling, 4*: 85-97

Rosensweig, Jeffrey A., and Lance Taylor (1990) “Devaluation, Capital Flows, and Crowding-Out: A CGE Model with Portfolio Choice for Thailand in Lance Taylor (ed.), *Socially Relevant Policy Analysis: Structuralist Computable General Equilibrium Models for the Developing World*

Scarf, Herbert E. (1967) “On the Approximation of Fixed Points of a Continuous Mapping, *SIAM Journal on Applied Mathematics, 15*: 1328-1343

Sen, Amartya K. (1963) "Neo-classical and Neo-Keynesian Theories of Distribution," *Economic Record, 39*: 53-64

Shoven, John B., and John Whalley (1972) “A General Equilibrium Calculation of the Effects of Differential Taxation of Income from Capital in the U.S.,” *Journal of Public Economics, 1*: 281-321

Sraffa, Piero (1926) “The Laws of Return under Competitive Conditions,” *Economic Journal, 36*: 535-550

Stanford, James O. (1992) "C.G.E. Models of North American Free Trade: A Critique of Methods and Assumptions." Washington DC: Testimony to the United States International Trade Commission, Investigation No. 332-317

Stanford, Jim (2005) “Economic Models and Economic Realty: North American Free Trade and the Predictions of Economists,” *International Journal of Political Economy, 33* (no. 3): 28-49

Stykolt, Stefan, and Harry C. Eastman (1960) “A Model for the Study of Protected Oligopolies,” *Economic Journal, 70*: 336-347

Steindel, Josef (1952, 1976) *Maturity and Stagnation in American Capitalism,* New York: Monthly Review Press

Stone, J. R. N. (1966) "The Social Accounts from a Consumer Point of View," *Review of Income and Wealth, 12*: 1-33

Taylor, Lance, and Stephen L. Black (1974) “Practical General Equilibrium Estimation of Resource Pulls under Trade Liberalization,” *Journal of International Economics, 4*: 37-58

Taylor, Lance, and Frank J. Lysy (1979) “Vanishing Income Redistributions: Keynesian Clues about Model Surprises in the Short Run,” *Journal of Development Economics, 6*: 11-29

Taylor, Lance et.al. (1980) *Models of Growth and Distribution for Brazil,* New York: Oxford University Press (for the World Bank)

Taylor, Lance, and Arnim, Rudiger von (2006) “Modelling the Impact of Trade Liberalisation: A Critique of Computable General Equilibrium Models,” Oxford UK: Oxfam International

Velupillai, K. Vela and Stefano Zambelli (2010) “Computing in Economics” Trento: Department of Economics, University of Trento

Xiao, Jingliang (2009) *A Dynamic Applied Financial General Equilibrium Model of the Chinese Economy* (unpublished Ph.D. dissertation), Melbourne: Department of Economics, Monash University

Young, Allyn (1928) "Increasing Returns and Economic Progress," *Economic Journal*, *38*: 527-542

Table 1: SAM for a one-sector open economy

	Value of output	Household income	Corp. income	Gov't. income	Foreign income	Investment	Domestic debt	Foreign debt	Totals
Value of output	aPX	PC		PG	PE	PI			PX
H'hold. income	$wL = w\lambda X$		iB_C	iB_G					Y_H
Corp. income	$rpK = \pi PX$								Y_C
Gov't income		T							Y_G
Foreign income	$eZ^*M^* = eZ^*mX$								Y_F
H'hold. FOF		S_H					$-\dot{B}$		0
Corp. FOF			S_C			$-PI$	$\dot{B}_C$		0
Gov't FOF				(S_G)			$\dot{B}_G$	$e\dot{\Delta}^*$	0
Foreign FOF					S_F			$-e\dot{\Delta}^*$	0
Totals	PX	Y_H	Y_C	Y_G	Y_F	0	0	0	

Table 2: SAM for the *General Theory* chapter 19 model

	Value of output	Household income	Corporate income	Investment	Totals
Value of output		c		g	u
Household income	$\omega\lambda u$		v		y_h
Corporate income	$r = \pi u$				y_c
Overall FOF		$s_h(\omega\lambda u + v)$	$s_c r$	$-g$	0
Totals	u	y_h	y_c	0	

Table 3: SAM for a two-country model incorporating an Armington treatment of foreign trade

	Cost	Arm.	Priv.	Exp.	Inv.	Cap. flow	Tot.	Exch. rate	Cost	Arm.	Priv.	Exp.	Inv.	Cap. flow	Tot.
Output	$-PX$	PX					0		$-P^*X^*$	P^*X^*					0
Supply	ZaX		ZC	ZE	ZI		ZA		$Z^*a^*X^*$		Z^*C^*	Z^*E^*	Z^*I^*		Z^*A^*
Priv.	QV	teZ^*E^*					Y		Q^*V^*						Y^*
FOF			S		$-ZI$	$e\dot{\Delta}^*$	0				S^*		$-Z^*I^*$	$-\dot{\Delta}^*$	0
Home Imp.		eZ^*E^*						$\leftarrow (-e) \times$				$-Z^*E^*$			
For. Imp.				$-ZE$				$\times (-1/e) -$		ZE/e					
Cap. flow						$-e\dot{\Delta}^*$		$\leftarrow (-e) \times$						$\dot{\Delta}^*$	
Tot.	0	ZA	Y	0	0	0			0	Z^*A^*	Y^*	0	0	0	

Table 4: Closure rules for an open economy model

	Standard closure	"Absorption" closure
Private balance: Investment and saving	Investment adjusts to savings, a function of income with various parameters.	Investment is pre-determined in the simplest specification.
Public balance: Government revenue and borrowing	The fiscal deficit is exogenous, financed by domestic and foreign borrowing. Direct taxes vary endogenously à la Johansen.	Direct taxes are proportional to income. The fiscal deficit is the difference between government spending and income. It is financed by endogenous flows of domestic and foreign borrowing.
Foreign balance: Exchange rate and trade account	The elasticities approach: the exchange rate adjusts to hold the trade account constant. Imports respond to relative prices; home country exports are set by total supply after other components of demand are satisfied.	Income or absorption approach: the exchange rate is exogenous and the current account adjusts according to home and foreign demand shifts. Capital flows between the home and foreign countries are endogenous.
Labor markets: Employment and wages	Employment is constant (Say's Law). With the price system scaled by the money wage and exchange rate, profit rates and/or returns to fixed factors adjust to make the real wage endogenous.	Keynesian closure: employment is determined by effective demand. The price system is scaled by the wage and exchange rate.

Table 5: SAM including a simple banking system

	Value of output	Household income	Corp. income	Gov't. income	Foreign income	Investment	Foreign finance	Bank finance	Totals
Value of output	aPX	PC		PG	PE	PI			PX
H'hold. income	wL		iB_C	iB_G					Y_H
Corp. income	πPX								Y_C
Gov't income		T							Y_G
Foreign income	eZ^*M^*								Y_F
H'hold. FOF		S_H						$-\dot{H}$	0
Corp. FOF			S_C			$-PI$		$\dot{L}$	0
Gov't FOF				(S_G)			$e\dot{\Gamma}^*$	$\dot{B}$	0
Foreign balance					S_F		$-e\dot{\Delta}^*$		0
For. reserves							$-e\dot{R}^*$	$e\dot{R}^*$	0
Totals	PX	Y_H	Y_C	Y_G	Y_F	0	0	0	

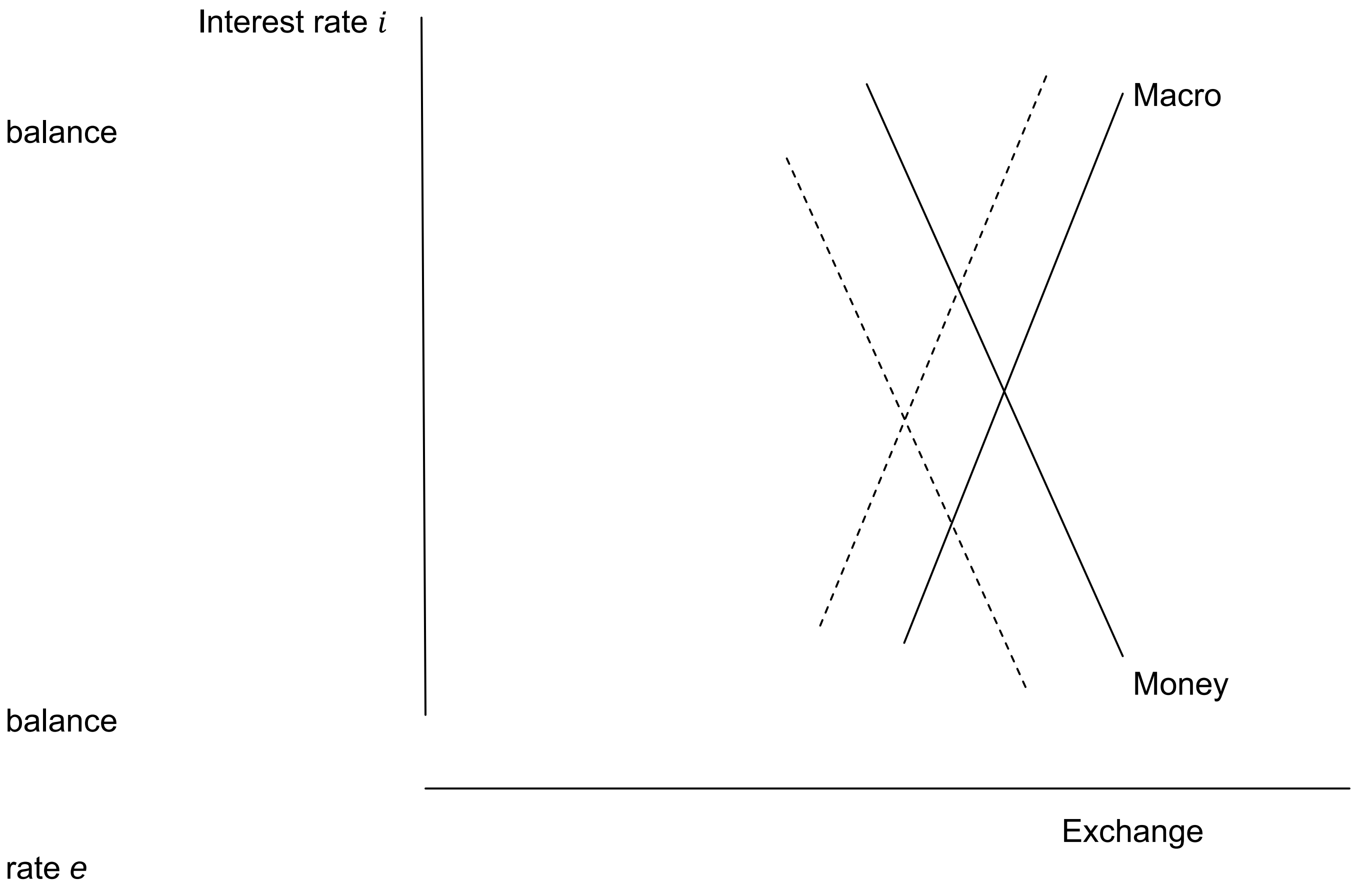

Figure 1: Interest rate and exchange rate interactions in China. The dashed lines represent reductions in consumption and central bank monetary injections.