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Computable General Equilibrium Models of Trade Liberalization: The Doha Debate

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Contents

Part I: Basic Ideas 3

I.1 Welfare Analysis 4

I.2 A Feel for the Numbers 8

I.3 Modeling Trade 9

Part II: CGE Models of Trade Liberalization in Practice 22

II.1 The Mainstream Microeconomic Stage 24

II.2 Problems in Modeling Trade 29

II.3 Illustrative SSA/ROW Data 31

II.4 Model Specification and Macro Causality in a Closed Economy 37

II.5 Open Economy (Armington) Macroeconomics 43

Part III: Simulations 53

III.1 Aim and Scope 53

III.2 Closure Rules 58

III.3 Results 61

References 74

Appendix: The model in Algebra

Figures 1–8

Part I: Basic Ideas

How can the effects on economic performance and well-being of nations from trade liberalization be estimated? Part I of this paper is a non-technical review and critique of the most widely used technique based on Computable General Equilibrium (or CGE) models. Part II goes over much the same material at a more technical level. Part III presents simulations with a simplified numerical model which are used to underline the main points. Conclusions appear in Part IV. An appendix describes the model in algebra.

Agricultural liberalization in the Doha Round of World Trade Organization (WTO) negotiations is the main topic. The background references comprise simulation models developed at the Global Trade Analysis Project (GTAP) at Purdue University and the LINKAGE project at the World Bank.

CGE models are not the only tool that economists use to try to assess the impacts of trade liberalization, but are the most widely applied for the WTO rounds. To see why we can consider an anti-liberalization example -- the tariff increases for steel that the US imposed in 2002. A “partial equilibrium” analysis of their impacts would investigate the American steel industry only. Presumably greater protection supporting higher prices would enable steelmakers to produce more and displace imports. Econometric studies of price and quantity responsiveness or (perhaps more usefully) consultation with industry experts could help policy-makers assess the implications.

But the price increases would in turn affect the automobile (and many other) steel-using industries adversely by driving up costs which would in part be passed along into higher prices. If imports of goods competing with American products incorporating steel were to rise sharply, there would be visible “general equilibrium” or macroeconomic repercussions. If the exchange rate – the pivotal price in any open economy – were to respond there would be strong feedbacks to the whole system. These would spill over to the rest of the world, and so on.

The CGE models around the Doha Round purport to quantify systemic repercussions of trade policy moves on a planetary scale. Worldwide econometrics is regularly applied at the one-sector macroeconomic level, and there is no dearth of pundits pontificating on global economic issues. However, such “expert” knowledge does not extend to detailed statements about what may happen to dozens of industries in scores of countries and regions if and when trade is further liberalized. Big models have a monopoly on such issues.

Unfortunately, there are serious questions as to whether the models – World Bank models in particular – have very much useful to say. They have many deficiencies, both conceptual and empirical, that relegate their results to being “suggestive” at best. We assess the models from various angles in this review and the longer, more technical Part II of this paper. In Part I we explain how the “welfare gains” that the models compute should be understood and sketch recent numerical results, go on to problems with the data they incorporate, and the many unconvincing aspects of their detailed specification.

I.1 Welfare Analysis

“Utopian capitalism” is a good label for the microeconomic approach to well-being at the foundation of mainstream models: all resources are fully employed, consumers are quite similar and behave in a fully rational fashion, arbitrage opportunities for the most part have been exploited so that prices for the same commodity in different places and times are the same (after correction for transport and storage costs, etc.)

But one or a few “distortions” remain in this world, mostly due to state intervention. In the present context these are usually taken to be tariffs (or “tariff-equivalents” of exchange controls, quotas, and other “non-market” restrictions) on imports and export or production subsidies. The question being asked is how much would well-being or welfare rise if the distortions were removed? How does the gain get measured?

The tried-and-true answer in conventional microeconomics is to figure out the “surplus” that would result from eliminating a distortion, say a tax on the price that producers charge for producing some good. The tax is supposed to force down output and drive a “wedge” between the price producers receive and the one that consumers pay with the government pocketing the

difference. Removing the tax would (i) transfer its erstwhile proceeds from the government to the private sector, (ii) allow producers' and consumers' prices to equalize, (iii) stimulate output, and (iv) allow producers to gain by selling more at a higher price and consumers to benefit from buying more at a lower cost.

There is a standard geometrical depiction of all this. In the familiar supply-and-demand diagram (with prices on the vertical axis and quantities on the horizontal), the *extra* benefits (after the transfer from the government) show up as a roughly triangular area nestled against the point where the demand and supply curves cross, above the latter and below the former (see Figure 2 in Part II). Welfare gains turn out to be measured by a "little triangle." The triangle should be compared to "large rectangles" showing the price x quantity magnitudes of the values of total sales by producers, total purchases by consumers, total taxes received by the government, etc.

The area of the triangle is small in comparison to those of rectangles – that is the first key point. Attempts to quantify welfare gains and losses in this manner began almost 50 years ago. Ever since, with standard specifications of the demand and supply curves the inevitable result is that the benefits amount to at most a few percent and more often to a fraction of 1% of the value of output. Gains from trade in World Bank models come out in this range in comparison to world GDP.

Tweaking the numbers going into the model can of course affect its results – gains can in some cases be negative or might be 0.2%, 0.7%, or 1.9% of the total value of output involved. The key parameters involved are "elasticities" of demand, supply, and other functional relationships tying together prices, quantities, incomes, and other variables. A demand elasticity, for example, gives the proportional or percentage change in the quantity purchased that would result from a percentage change in the price. If the elasticity is (minus) two, a 1% price increase would make the quantity demanded decrease by 2%. Depending on the relationships being studied, econometrically estimated elasticities range from fractional values up to something less than ten.

World Bank modelers usually opt for relatively high elasticity values in their creations. One reason (others are presented later) may be that estimated welfare gains from eliminating

distortions usually turn out to be higher when elasticities are larger. In the little triangle story, bigger demand and supply elasticities flatten the demand and supply curves, generating a greater quantity response to a given price change which increases the triangle's area.

The fact that elasticities are inferred from market data means that they reflect outcomes of many individual decisions. The only possible rationale for their use in welfare calculations is that consumers and producers as groups behave essentially alike. Utopian capitalism relies on the implicit postulate that "economic agents" are all very similar. Does the postulate make sense? Even if it does, why bother to do the computations when one can safely assert a priori that the gains will be somewhere in the range -0.5% to +2-3%, depending on one's choices of elasticities?

The mainstream response is that the models can provide detail on who gains and loses. That assertion turns out to be tricky. Because they deal with entire economies the models necessarily take on a macroeconomic character. Forces arise at the macro level that can strongly perturb micro level welfare calculations.

For example, tariff reduction will increase the fiscal deficit. LINKAGE assumes direct taxes on consumption rise to drive the deficit back to its initial level. In olden times (say 1950) the standard view was that the tax increase would exactly offset the reduction in the import price a lower tariff would induce. With fiscal repercussions thereby ruled out, "substitution" responses to the lower tariff would rule, giving rise to little triangle welfare gains from cheaper imports.

Unfortunately, the good old interpretation does not apply to LINKAGE. Precisely because of its widely accepted "Armington" specification of trade responses to price changes (much gory detail to follow) the *direct* impact of the higher tax in reducing aggregate real consumption is greater than the positive *indirect* effect of tariff reduction on cutting its cost. If the aggregate declines then so must sectoral consumption levels as well. Little triangles shrink for macroeconomic reasons.

On the other hand, if production or export subsidies were reduced, then the government could lower taxes on households and consumption would rise. Generously interpreted, the resulting welfare gains could reflect greater economic efficiency, in the sense that producers

employ resources in a more productive way instead of being misled by “wrong” price signals from the subsidies. But that amounts to ignoring the fiscal linkage.

Of course, many other things are going on in a CGE solution which can offset such causal chains, but our simulations with a small model in Part III suggest that fiscal linkages are quite important (especially when elasticities take on more “reasonable” values than the Bank habitually stipulates).

Secondly, the macro level dimensionality of realistic CGE price systems may be low. Although price movements at the sectoral level are affected by specific tariff and subsidy changes, in a sensible specification overall movements in prices can be viewed as being driven by the wage, profit, and exchange rates – a country’s system of macro prices has three (or possibly a few more) degrees of freedom.

This restriction can constrain micro quantity and price responses. GTAP has devoted enormous effort to putting together numbers about trade and tariffs worldwide. Its full data set covers 57 sectors in 87 countries/regions. At first glance, welfare calculations in a model based on all that data seem to amount to sliding around, expanding, and contracting big rectangles in 87 x 57 = 4959 demand-supply diagrams and figuring out 4959 price changes that will make everything balance out.

Limited dimensionality in the price system can make the dance of the rectangles less predictable. A sector’s demand (P_D) and supply (P_S) prices in trade models are related by a formula such as $P_D = e(1+t)P_S$ in which t is the relevant ad-valorem tariff rate and e is the exchange rate linking domestic to foreign prices. Along with shifts in aggregate consumption, sector-level price shifts will then be driven by changes in t and e, with e coming from the macro level. Even if the tariff rate t is reduced so that there would presumably be a welfare gain, the change could be offset by an increase or devaluation in e.

The bottom line is that given how little we know about data and econometric specifications, nothing precise can be said about what will happen to the areas of all the little triangles when liberalization makes the big rectangles dance. A statement to the effect that a household getting wage income from sector Y in country Z will gain 1.3 cents in consumers’

surplus per day forever from tariff reduction looks nearly meaningless. Some sectoral triangles will shrink and others expand in response to differential effects on consumers and producers. Overall, winners in principle could bribe or "compensate" losers so that everyone is better off. In practice compensation rarely if ever occurs, making calculations of improvements or losses in well-being under utopian capitalism even more elusive.

I.2 A Feel for the Numbers

Many models of the effects of trade liberalization have been constructed since they were invented thirty-odd years ago. There were two waves 15-20 years back (with several contributions substantially more interesting analytically than the current crop) in connection with the Canada-US-Mexico debates about the CUFTA and NAFTA "free trade" agreements. There have been numerous subsequent efforts in connection with the WTO negotiations. HM Treasury (2004) lists more than twenty models that dealt with the Uruguay round and at least as many address Doha. For the reasons presented above, these "global" exercises always take the CGE form. Some also try to say something about the impacts of trade liberalization on poverty.

One important point about recent Doha models is that their projected benefits have been shrinking over time, as emphasized by Ackerman (2005). GTAP 2002 was talking about $254 billion of benefits for the world from complete liberalization and $108 billion for developing countries. (These numbers should be compared to a worldwide GDP on the order of $30 trillion, with $5 trillion for developing countries.) The estimates for 2005 shrank to $84 and $22 billion respectively. The reasons are obscure – perhaps there is less protection to reduce after the Uruguay Round and some elasticities may have been lowered. Simulations for the sorts of tariff reductions being contemplated for the Doha Round reduce these estimated welfare gains by around two-thirds, more for developing countries.

The standard approach to estimating the effects of liberalization on the poor is via a "poverty elasticity" which is supposed to measure the percentage decrease in a "headcount ratio" (the share of the population with income below an absolute poverty line such as $2 per day) which would result from a one percent increase in (say, low wage) income. These elasticities

range from fractional values to two or three, depending on the country, sector, or time period under consideration.

This approach is obviously mechanistic and crude. It also provides depressing results. For its own reasons (to make benefit numbers look bigger?) the World Bank prefers to run its LINKAGE projections out to 2015. By then, Doha-style liberalization would reduce the number of poor ($2 per day poverty line) by six million people in a global total of 1946 million!

I.3 Modeling Trade

With such meager projections, it seems likely that the models will have less impact on the liberalization debate in the future than they had in the recent past. Nevertheless, it is worthwhile to discuss their built-in assumptions and structure as well as modifications that could be made so that they could address questions such as the effects on employment and capital inflows of liberalization. We begin with data and go on to details about how trade is modeled and macroeconomics. The discussion will be brief, with more detail appearing in Parts II and III.

Data

CGE modelers (ourselves included) take a cavalier approach to data. For a one-country model, the basic sources are the national income and product accounts (NIPA), flow of fund (FOF) accounts, government accounts, balance of payments (BOP) accounts, and an input-output table. In principle *complete* sets of these accounts are required, at least for a model's "base" or "reference" year. They are combined into a social accounting matrix or SAM, which can be viewed as a spreadsheet containing double entry bookkeeping for transactions across the dozen or three "sectors" or "industries" included in the model. Figure 3 in Part II is a simplified two-sector, two-country SAM with trade between sub-Saharan Africa (SSA) and the rest of the world (ROW) extracted from GTAP data. Among other features it indicates that there are vast differences in income levels and economic structures between the two regions. The contrasts make it difficult to see how the implicit assumptions about uniformity of economic actors underlying utopian capitalism can reasonably apply to Figure 3's world.

Any sector in the SAM (foodgrains, say) will include many goods (several varieties each of wheat, rice, soybeans,….), each of which may have its own tariff rate. The "tariff" in a model for

the foodgrain sector has to be some sort of average of rates for the specific goods, usually with properties that are poorly understood.

A CGE model's equations come in two sets. The first comprises the accounting "identities" that bind together the bookkeeping of the SAM. The second includes "behavioral relationships" such as cost decompositions for sectoral outputs, equations relating foreign and domestic prices of imports and the goods they compete with at home, functions describing consumer behavior, etc. A typical equation could say that a sector's demand for labor depends on the real wage (nominal wage divided by output price). It will have a "slope" parameter (often an elasticity) and an "intercept." Most modelers postulate the slope on the basis of some source (econometrics, prior beliefs, adivination,…) and then can calculate the intercept so the function is consistent with the data from the base year SAM.

Needless to say, this procedure is not wholly convincing. Who knows what the slope "really" is, and why should data from some arbitrary base year be forced upon the behavioral relationship? One implication is that if foodgrains are 10% of total imports in the base year, that share will not change very much for "reasonable" elasticities and tariff changes. CGE models cannot contemplate major realignments in the composition of trade – they could not have foreseen the explosion in trade over the past 20 years in China.

GTAP is the basic data source for almost all trade models. It provides base year SAMs for all the countries and regions it includes and data on international trade flows and tariffs. Its country level SAMs incorporate macroeconomic data which are incomplete at best (details in Part II). We are not in a position to comment on the reliability of the trade data, but can offer the thought that any economist who has ever worked on international, macro, or poverty issues in any developing country knows that there are big holes in the NIPA , FOF, and BOP, with many numbers made up from more or less thin air. This caveat applies to CGE computations a fortiori.

Armington Trade

There is a gothic quality to World Bank CGE model architecture. The great cathedrals, after all, have simple floor plans (like Figure 2 in Part II). But with their arches, towers, gargoyles, spandrels, and stained glass they are immensely complicated structures. Mainstream trade

modelers have spent the last three decades adding similar features to basically simple accounting, making their productions extremely difficult to understand and sometimes downright misleading (as in the fiscal effects discussed above). Much obfuscation comes from their "Armington" (1969) specification of foreign trade.

The trick is to treat a sector's domestic output and imported "similar" goods as imperfect substitutes so that if the price index of one category goes down more of it will be consumed (and less of the other will be consumed) but there will not be complete substitution. The strength of the response is gauged by an "elasticity of substitution" discussed below.

The benefits include the fact that the Armington specification provides a fairly simple, operational model structure for trade. It seems reasonable that a household in the USA might decide to buy a typical "American" or "foreign" car.

But there are many drawbacks. The idea that there is *national* product differentiation ignores the fact that characteristics of products are determined by firms, not countries. A Toyota is a Toyota, be it manufactured in Japan or the US. Under the hood of a Ford is a Ford engine, regardless of whether it was assembled in Ontario, Mexico, or Detroit. Much international trade is *intra*-firm, for which the Armington setup is beside the point. 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 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" start demanding high tech, capital-intensive machinery from abroad because the Armington equations won't let them.

The implication is that Armington models increase the estimated benefits of liberalization by default because reduction of deadweight losses from tariffs as in Figure 2 in Part II is enhanced by cutting back "distortions" due to monopoly power.

The specification can be extended to several classes of imports, for example from intra- and extra-regional suppliers. One import type is an imperfect substitute with the other type and domestic goods. Going a step further (and without much empirical backing), hard-core CGE modelers like to sub-divide or "nest" such categories of imports (not to mention exports, production inputs such as land and various labor skill categories, components of the consumption basket, and so on) up to three levels of disaggregation or more to "describe" their substitution possibilities in fine detail. For example, intra- and extra-regional imports might trade off to generate an "overall" import category, which would then substitute with domestic goods. Or maybe the category nesting should go the other way. Spandrels between substitution possibilities and other triangles abound in this line of gothic architecture, making it all the more difficult to penetrate what is going on.

Finally, the Armington technique introduces the fiscal biases discussed above. To see how, we have to turn to macroeconomics.

Macroeconomics

With all their sectors, import and export categories, and diversified production inputs, the LINKAGE/GTAP models cleverly pretend to do microeconomics. But as we have seen they are macroeconomic creatures by construction. The implications are worth tracing out. The best way is to think through the models' macro structure. The process will take a few pages but may help elucidate how strange many World Bank modeling assumptions really are!

The place to begin is with Keynes (1936), specifically Chapter 19 of *The General Theory.* Therein, he discussed an economy in which determination of prices of goods (or "sectors") and their outputs are *not* closely linked. At the outset, all CGE models share this trait. It can be illustrated using a model with just one sector, bringing in multisectoral complications from time to time. We first deal with costs of production.

The price of output has to break down into its costs. Leaving aside intermediate inputs such as the wheat that goes into flour which just complicate the discussion, we can focus on inputs of labor (paid a wage) and capital (which earns a rate of profit). Price decomposes into labor and capital costs. A CGE model takes this truism under its wing by including a "cost

function" which states that the output price is a fancy non-linear average of the wage and profit rates. Built into the formula is an elasticity of substitution which in this case indicates how strongly the labor/output and capital/output ratios will shift if the wage and profit rates change. Using a technical trick that Keynes called the "second classical postulate" and that modern microeconomists call "Shepherd's Lemma" one can write down equations describing these reactions quantitatively. Finally, "real output" and the "output price" in a way are the two sides of a coin (or in the jargon are "dual" to one another). The "value of output" is their product. The value of wheat output is the product of the number of tons produced and the price of wheat. Current price GDP is the product of "real" GDP measured in terms of some base year set of prices and a price index.

According to the Armington story, the same concepts apply to foreign trade. The value of supply in a sector or economy-wide will be the value of imports plus the value of domestic output as just discussed. The post-customs price of imports is their foreign price (in dollars, say) transformed into domestic money terms by multiplying by the exchange rate and marked-up by the tariff rate (as shown algebraically above). "Real" imports are just their dollar value.

The Armington trick is to assume that the value of supply can be split into price and quantity components. If so, then the supply price, like the domestic output price discussed above, can be written as a fancy non-linear cost function or average of the post-tariff import price (index) and the output price. Because it is a blend of domestic and import prices the Armington supply price will *not* rise one-for-one in response to a higher import tariff. This partial response is at the root of the fiscal problem mentioned above and sketched in more detail below.

"Dual" to the Armington price will be a real aggregate output indicator ("produced" from real domestic products and imports). From Shepherd's Lemma, ratios of real imports and domestic output to this index of "supply" will be determined by the ratios of import cost and the output price to the supply price. The key parameter is an "Armington elasticity" (of substitution) which shows how strongly the ratios respond to price changes. High elasticities expand little triangles and enhance the benefits of trade liberalization.

Leaving aside foreign trade considerations for the moment, the next step is to think through how domestic output gets determined in a closed economy. The simplest entry to the story is to assume that the wage, profit, and exchange rates are all fixed, setting the output price from its cost function as well. So far, prices and output are pretty much disjoint.

With all prices fixed, labor/output and capital/output ratios will be determined (again by Shepherd's Lemma). Multiplying each ratio by output and the appropriate "factor price" (wage rate for labor and profit rate for capital) gives labor and capital incomes. Their sum or total income is thereby determined by output and the fixed factor prices. After saving and taxes are deducted, income left over can be assumed to go for consumption. In other words consumption is a function of output. (Keynes thought that his consumption function should be quite stable as a "fundamental psychological law." In most countries it is fairly unstable. One should not pay attention to pop psychology even when it comes from a genius.)

The basic demand-supply balance in an economy (or a sector) states that

domestic output + imports = aggregate supply

= consumption + capital formation + government spending + exports ,

with imports and exports playing no role in a closed economy.

Suppose that firms choose their levels of capital formation ("investment" in economists' usage) and the government decides how much to spend. Then since consumption is determined by output, the closed economy balance equations can be solved for output itself as a function of capital formation and government spending.

The standard thought experiments are to trace through the implications of higher capital formation or an increased flow of consumption induced by a given level of output (which, if you think about it, means that either saving or taxes must decrease as a share of output). Both can easily be seen to raise output and (though the labor/output and capital/output ratios) employment of labor and capital. If we bring trade back in, the same logic applies with the rest of the world setting "our" level of exports. Imports and aggregate supply will follow from Armington mumbo-jumbo.

The foregoing is basically Keynes's *General Theory* model for the non-financial side of the economy. Again leaving out foreign trade for the moment, we can now describe LINKAGE/GTAP macroeconomics. The *bête noire* of the *General Theory* is "Say's Law" which asserts that all resources are fully employed. Although they habitually use the word "fixed" in place of "full," mainstream CGE models postulate full employment of labor and capital.

In practice modelers first must peg some price to scale the whole system. For present purposes it is convenient to follow Keynes and use the money wage (so many units of local money per hour, a number set by convention) as a "numeraire" although the Bank models use an international price index. Then with the wage pre-determined the models include an equation stating that the profit rate adjusts to bring the product of the capital/output ratio and output (that is, the demand for capital at a given level of output) into equality with the fixed capital stock. By the miracles of double-entry bookkeeping built into the SAM, the demand for labor will then come into equality with its supply (This trick is called "Walras's Law" in the literature. It basically says that if all other markets clear, then any single market such as the one for labor has to clear as well.)

Note that through the cost function the price level (or levels of all output prices in a multisectoral set-up) now moves in response to changes in the profit rate, input-output ratios are therefore shifting, consumption patterns are adjusting to a new set of prices, and so on. Forcing full employment on the system breaks down Keynes's wall between price and output movements. Moreover (this gets slightly technical) if the economy is on its cost function and obeys the hiring rules built into Shepherd's Lemma, it can also be viewed as having a "production function" ("dual" to the cost function) which determines output from the fixed supplies of labor and capital. Full employment sets the level of output from the supply side.

If output is being determined in this fashion, how can it also be set by the demand-supply balances stated above? The answer is that it cannot be. Still ignoring foreign trade, a fixed level of output will determine the level of consumption. With the government continuing to set its spending, the only variable that could possibly adjust to bring equality of output and demand is capital formation or investment. Firms can no longer make independent investment decisions. The writ of Say's Law covers a wide swath of macroeconomic causality.

In contrast to the thought experiment above, a lower saving rate (or higher consumption) will now reduce capital formation at a given output level. In a Keynesian world higher consumption stimulates output at a given level of investment (and may possibly stimulate more investment in the future). The usual summary statement is that "saving determines investment" in mainstream models while "investment determines saving" for Keynes. One more digression is worthwhile to illustrate the details and then we can get on to foreign trade and the impacts of tariff reduction.

The topic is flow of funds accounting, which appears in primitive fashion in almost all World Bank CGE exercises. We can consider three "institutional sectors": the private sector, government, and the rest of the world. Each one's FOF account states that its "sources" of funds for financial purposes must equal its "uses." Sources are saving plus increases in financial liabilities. Uses are capital formation plus increases in financial assets. Saving, in turn, is income less expenditures for taxes and consumption (and net interest payments in a more complete accounting framework). An institutional sector's saving minus its capital formation is its "net lending," which in turn equals the increase in its financial assets minus the increases its liabilities.

In the GTAP/LINKAGE models, the private sector's flow of funds is

private saving = capital formation + new loans to the government .

The government's flow is

government spending – net revenue = new loans from the private sector

+ new loans ("foreign aid") from abroad .

The rest of the world's flow is

home country imports – exports = new loans from abroad .

Combining all these balances gives an overall macro equilibrium condition,

(capital formation – private saving) + (government spending – net revenue)

+ (home country exports – imports) = 0 .

Suppose that Say's Law rules in an economy closed to foreign trade (so that imports, exports, and foreign aid all equal zero). In addition, most World Bank models freeze financial transactions between the private sector and the government, setting new loans to an

exogenously fixed value. We already know that fixed employment determines the saving level so that from the private flow of funds with new loans fixed, investment must adjust endogenously to equal saving minus the loans.

If government spending on goods and services is set by policy and loans from the private sector are fixed, the only remaining variable is government net revenue, made up of taxes on household income (in the open economy context one should also add tariff receipts and subtract subsidies on exports). The household taxes have to change to hold revenue constant if any of the other variables shift.

These are peculiar assumptions. Such adept fiscal programming is never observed (let alone over 15 years as assumed in LINKAGE model simulations!). There are many other ways in which economies arrive at macroeconomic equilibrium as defined just above. For example, in Keynes's closed economy story saving and government revenue (or "leakages" from income flows) depend on output while investment and government spending ("injections") are pre-determined. Setting total injections equal to total leakages fixes the level of output via adjustments in levels of saving and revenues. This scenario is at least as realistic as Say's Law.

At long last we can consider open economy macroeconomics, in effect as it existed half-a-century ago. The gist is that World Bank models try to adopt (not completely successfully) an "elasticities" approach to determination of the balance of payments. The emphasis is on how movements in the exchange rate and other prices affect imports and exports.

In the 1950s it did (and still does) also make sense to consider a more Keynesian "absorption" approach in which the level of economic activity (and the forces impinging upon it) affect the trade balance. It is reasonable to think through the implications of both approaches in any applied context, but the Bank rarely does that. Indeed, the LINKAGE specification has a big dose of absorption macro built into it on the fiscal side but as far as we can tell nobody at the Bank has ever noticed.

A modicum of algebra will ease the analysis. Let Z be the Armington supply price (discussed above) for SSA and Z^* the supply price for ROW. The post-tariff cost of SSA's imports will then be $(1+t)eZ^*$ where e is the exchange rate (SSA currency to ROW currency)

and t is the import tariff. If ROW has no tariff, its import cost will be Z/e. Finally let P and P^* be output prices in the two countries. By Shepherd's Lemma the SSA import/output ratio will depend (inversely) on the price ratio $(1+t)eZ^*/P$ and the ratio in ROW will depend on $(Z/e)/P^*$. The quantity responses will be stronger, the greater are the Armington elasticities for the two regions.

Now consider the external flow of funds for SSA, restated from above as

SSA imports – ROW imports = New loans from ROW to SSA .

With this balance in hand we can do LINKAGE-style open economy macro, assuming that ROW sets the level of its new loans in terms of its own currency but (like the USA) has no policy reaction to shifts in the exchange rate. A natural scaling variable for the price system is the ROW wage rate.

In SSA the wage and profit rates are supposed to adjust to make demand equal to supply for labor and capital respectively and the ROW profit rate is assumed do the same for capital there. Shifts in the exchange rate will modify import levels so presumably it can vary to clear the foreign balance as stated above. After all this happens demand for ROW labor will automatically adjust to meet a fixed supply.

An obvious question is what will be the consequences if SSA cuts its tariff. Presumably imports will increase as the price ratio $(1+t)eZ^*/P$ goes down. There are two adjustments that can happen to shift imports back downward.

First, taxes on households have to go up to hold government net revenue constant if tariffs are cut (correspondingly taxes would fall if export subsidy outlays were reduced). However, for the reasons discussed above the tariff reduction is *not* fully passed into a lower Armington supply price (the Armington price is a complicated average of both import and domestic output costs). The tariff/tax package pulls aggregate demand down with the tax increase and pushes it back up with lower tariffs. Pull is stronger than push so that aggregate consumption will decline, reducing imports. This is the absorption wrinkle in the LINKAGE specification.

The other possibility is an increase in e which will make SSA imports more expensive and also induce the ROW import coefficient to rise. If the fiscal and exchange rate responses together are strong enough, external balance for a given capital flow from ROW to SSA will be restored.

Higher Armingon elasticities make the role of the exchange rate adjustment greater. The Bank also likes to emphasize how liberalization will rearrange trade flows in the direction of exports through the induced devaluation. Of course, this result is already built into their model.

Because it did not incorporate Armington assumptions, the traditional elasticities literature could sidestep the fiscal effect and focus on exchange rate adjustments only. They will go through successfully if a "Marshall-Lerner" condition is satisfied. The Armington elasticities between domestic output and imports in SSA and ROW are the key parameters, and most open economy macro people think of them as being in the range from one to three. Bank models often peg them in the range of three to six and some studies such as Cline (2004) have worked with elasticity values in the teens!

Perhaps being overly cynical, one can think of two justifications. One is that, as we have seen, higher elasticities tend to enhance welfare gains from eliminating distortions.

The other is that a devaluation or increase in the exchange rate *e* will reduce the world price Z / e of SSA exports and shift that region's terms of trade adversely. The shift will be *stronger*, the *lower* is ROW's Armington elasticity because its demand response to devaluation will be weaker.

So higher elasticity values attenuate or even reverse adverse shifts in the terms of trade in response to devaluation. The problem in the context of reducing protection for agriculture is that price elasticities of demand for products from the sector are *low* (indeed often estimated to be less than one). This is the first lesson that agricultural politicians and economists learn. The implication is that it makes sense to support agricultural prices because their downward excursions in response to transient upswings in supply or downswings in demand are likely to be so large as to be politically unacceptable. Adverse shifts in the agricultural terms of trade in response to tariff reductions look almost inevitable for usually accepted elasticity values as has been known for a long, long time. Is that why World Bank economists prefer to boost their estimates from something like 0.5 to 5?

It is worthwhile to think through scenarios with an endogenous fiscal deficit so that the Bank's odd treatment of household taxes does not apply. Then, because tariff reduction cuts

prices and eats into government net revenue it might be expected to stimulate aggregate demand in addition to raising the import coefficient. Various adjustments can ensue. We can trace through two examples for SSA, assuming that feedback effects onto ROW are relatively weak.

One is simply the World Bank scenario discussed above. Alternatively, the SSA exchange, profit, and wage rates could be held constant and investment could be exogenous. Then the SSA external deficit, government borrowing, and output could all change endogenously in a pure "absorption" scenario. Illustrative numbers are attached to these scenarios in Part III.

A final note on modeling: the discussion here has been set up in terms of open economy macroeconomics. The LINKAGE/GTAP models don't deal with the implications of tariff changes in quite that way. Rather, as discussed in detail in Part II they start their analysis from the perspective of international trade theory which does *not* incorporate exchange rates.

From a trade theory perspective the price of SSA exports is just Z instead of Z/e and the post-tariff import price in SSA is $(1+t)Z^*$ so Z^* is not multiplied by e. Instead of the exchange rate, the supply prices Z and Z^* will have to adjust to clear the trade balance for a given level of new loans from abroad. An immediate question as how can these prices vary under full employment when their levels are being determined from the side of costs?

Fortunately for the models this problem can be swept away if another input besides labor and capital is needed for the production of the good whose price is P. The input could be "fixed capital" (by sector), "land," some "specific factor" etc. Then the tariff rate and supply prices can determine import prices as above. The Armington and production cost functions set up a relationship among the output price P, the supply price Z, and the import price in SSA. If Z adjusts to clear the trade balance, then P can adjust as well through changes in the cost of the extra input. The price "mapping" runs from import prices through Z to P and then on to the endogenous cost of the input.

This trade theory pricing story is more complicated, but broadly consistent with the one from open economy macro (indeed, Bank documents often talk about "changes in the real exchange rate" as driving their model results). It is complicated further still by the GTAP/LINKAGE modelers' predilection to built in nests upon nests of differentiated production

inputs. World Bank model specifications are wonderfully consistent in trying to hide a macroeconomic lantern under a heavily filigreed microeconomic bushel.

Part II: CGE Models of Trade Liberalization in Practice

In this part of the paper we attempt to describe the essentials of CGE models of the sort used by the GTAP (Purdue University) and LINKAGE (World Bank) projects, repeating and extending material already covered in Part I. The reference models share a common intellectual ancestry and associated personnel.[1] We use some mathematics throughout the discussion. In the spirit of the recent bestsellers by Wolfram (2002) and especially Penrose (2005) who deal with far more recondite material, arguments are set up to be accessible to readers who "skip the equations". The emphasis is on aggregate or one-sector macroeconomics, with multisectoral twists brought in from time to time.

One major issue is that the LINKAGE/GTAP models draw heavily on standard international trade theory, essentially a branch of microeconomics. As argued below, their methodology for calculating the benefits of liberalization has dubious empirical relevance at best. This problem is exacerbated by the particular specification of trading behavior that they adopt. There is no reason to take seriously the exact numbers about gains from liberalization that they crank out, and their order of magnitude could be estimated without resorting to the computer in any case.

Even more important is the fact that in simulations claiming to represent the trading world as a whole, macroeconomic questions inevitably arise. The widely used models mangle macro level data and fail to trace through economy-wide implications of trade liberalization. It makes more sense to think through their behavior in terms of open economy macro theory rather than international trade theory micro. That is what we do here.

To repeat Part I's anti-liberalization example of what CGE models try to do, consider the tariff increases for steel that the US imposed in 2002. A strictly "partial equilibrium" analysis of their impacts would investigate the American steel industry only. Presumably greater protection

[1] CGE modeling of trade liberalization goes back around 30 years – Taylor and Black (1974) may be the first published paper. The World Bank picked up on CGE models in general soon thereafter and has applied them ever since in many areas of its interest. The LINKAGE/GTAP specifications fit firmly within this tradition.

supporting higher steel prices would enable it to produce more and displace imports. But the price increases would in turn affect the automobile (and many other) steel-using industries adversely by driving up costs which would in part be passed along into higher prices. If imports of goods competing with American products incorporating steel were to rise sharply, there would be visible "general equilibrium" or macroeconomic repercussions. If the exchange rate – the pivotal price in any open economy – were to respond there would be strong feedbacks to the whole system. These would spill over to the rest of the world, and so on.

The standard models cut off this sort of analysis by assuming that (i) fixed or "full" employment of labor and capital is maintained everywhere in the world as a consequence of (ii) movements in industry cost structures which are complicated and difficult to trace, (iii) each country's trade deficit (or surplus) stays constant after liberalization, and (iv) completely flexible taxes on households enable each country's internal macroeconomic adjustments to go through smoothly.

As described in detail below, these assumptions throw the price adjustment burden of keeping the balance of payments and employment constant onto changes in land rents, "sector-specific" costs, trade and transport margins, and so on. These can be metaphorically summarized as movements in the "real exchange rate" (though exchange rates do not figure in most micro trade theory). But what if the exchange rate doesn't respond because it is driven by events in financial markets and not trade? Or the trade deficit widens after liberalization? Or unemployment goes up? The GTAP/LINKAGE models simply do not consider these possibilities, basically assuming that "the price system" will respond to liberalization in such as way as to increase overall well-being.

So to explain the inadequacies of standard models we have to deal with both micro and macro issues. Comparisons and contrasts between trade theory and open economy macro are brought in where appropriate. We concentrate on agricultural sector liberalization in the context of the Doha Round. With just two people on the project, we didn't see a lot of potential payoff from diving into the full complexity of, for example, the GTAP 6 (2005) global database encompassing 57 production sectors in 87 countries/regions. Rather we chose to work on an illustrative 2-

country, 3-sector model based on GTAP numbers. The “countries” (or regions) are sub-Saharan Africa (SSA) and the rest of the world (ROW). We study the effects on each of tariff and subsidy reductions in a framework that is relatively easy to manipulate and understand. The model is a stylized condensation of the World Bank constructs and as such suffices to deal with the methodological issues we present.

We begin with a brief review of standard approaches to calculating the “gains from trade” that liberalization is said to generate. We then elaborate on complications in describing trade flows in a multi-country multi-commodity environment. The next step is to provide a data set for the SSA/ROW world in the form of a social accounting matrix (or SAM), which leads naturally into discussions of closed and then open economy macroeconomics. Part III describes our illustrative model and its results.

II.1 The Mainstream Microeconomic Stage

As noted in Part I, “Utopian capitalism” (Sagoff, 1988) is a good label for the microeconomic approach to well-being at the foundation of mainstream models: all resources are fully employed, consumers are quite similar and behave in a fully rational fashion, arbitrage opportunities for the most part have been exploited so that prices for the same commodity in different places and times are the same (after correction for transport and storage costs, etc.)

In slightly fancier language, because of price arbitrage the cost at the margin of producing a commodity is usually equal to the marginal well-being its consumption generates. The economy is close to being “Pareto optimal.”

But one or a few “distortions” exist in this world, mostly due to state intervention. In the present context these are usually taken to be tariffs (or “tariff-equivalents” of exchange controls, quotas, and other “non-market” restrictions) on imports and export or production subsidies. The question being asked is how much would well-being or welfare rise if the distortions were removed? How does the gain get measured?

Historically the standard methodology was proposed by French engineer-economists such as Jules Dupuit (1844) in the first half of the 19th century. Figure 1 illustrates the argument.

A bridge has just been constructed and a toll P_C per crossing (presumably collected over a number of years) will cover its costs. The assessment of benefits depends on a series of hypothetical calculations. If a very high toll is levied, there would be a very small number of crossings as indicated by the vertical bar to the far left of the diagram. A somewhat lower price would induce more people to cross as indicated by the two leftmost bars, and so on.

Figure 1

The area covered by all the vertical bars until the toll falls to P_C sums the "willingness to pay" of everyone who wants to cross at that cost. The more-or-less triangular shaded tract is Dupuit's proposed measure of the benefit from building the bridge.

Note that (i) we are talking about *different* people crossing the bridge here – those who are willing to pay a lot, then those who would pay a bit less, etc.; (ii) this pricing scheme is the one a discriminating monopolist could use to extract maximum "surplus" from its customers; (iii) as such there is a big informational problem in extracting the data to plot the curve.

Figure 2 illustrates the contemporary version of this approach, in a "deadweight loss" calculation characteristic of Utopian capitalism in which consumers are presumed to be essentially the same. In an undistorted market for a single good with the usual demand and supply curves, P^* would be the equilibrium price and Q^* the quantity produced and consumed. Imposing a sales tax would drive production down to Q_S. The price consumers pay would rise to P_D and producers would receive just P_S per unit sold. The shaded rectangle shows the breakdown of tax receipts between lower "consumers' surplus" (measured by the area under the demand curve) and lower revenue for producers.

Figure 2

So far the private sector's loss is the government's gain. But there is also a "little triangle" to the right of Q_S between the demand and supply curves which is supposed to measure the welfare loss from imposing the tax. Removing the tax would evidently produce a similar gain.

Calculating the size of little triangles is the methodology used by CGE modelers to asses the gains from liberalizing trade.

The area of the triangle is small in comparison to the "big rectangles" representing tax receipts and the value of output. Attempts to quantify welfare gains and losses in this manner began almost 50 years ago (Harberger, 1959).[2] Ever since, with standard specifications of demand and supply curves the inevitable result is that the benefits amount to at most a few percent and more often a fraction of 1% of the value of output. Gains from liberalizing trade in World Bank models often come out in the 0-1% range in comparison to world GDP.

Such "findings" can of course be manipulated by clever modelsmiths. The gains can be made to be 0.2% or 0.7% or 1.9% by suitable choices of "elasticities" and other parameters. The problem is that econometric and other statistical procedures *cannot* narrow the range of parameter values sufficiently to decide between one story or another – there is too much noise in the data.

Here is an example. Let X be output of the good in question, with a supply function $X = (P_S / B)^{1/\theta}$ in which θ is the elasticity of marginal cost with respect to output and B is a scaling factor. Suppose that the demand function is $X = (P_D / A)^{-\eta}$ with η as the elasticity of demand. This formula follows from a "quasi-linear utility function" $u(X)$ in which the elasticity of u with respect to X is $(\eta - 1)/\eta$ so for the story to make sense we need $\eta > 1$ (Varian, 1992). Assume that

$$P_D = (1 + t)P_S = \tau P_S \qquad \text{(DS)}$$

for an ad valorem tax rate t. Let $\hat{X} = dX / X$ be a proportional change in X. Substitution for P_D and P_S from the demand and supply functions into equation (DS) and logarithmic differentiation show that $\hat{X} = -\eta /(\eta + \theta)\hat{\tau}$. An increase in the tax rate (from zero) makes output fall. The proportional loss in utility from lower consumption of X works out to be $\hat{u} = -[(\eta - 1)/(\eta + \theta)]\hat{\tau}$. The

[2] University of Chicago economics grad students used to put out a calendar with caricatures of their professors. Harberger was the superhero "Triangleman" with a diagram like Figure 2 emblazoned on his chest.

loss will be *greater* for *higher* demand (η) and supply ($1/\theta$) elasticities. Intuitively, higher elasticities "flatten" the demand and supply curves in Figure 2 and make the area of the little triangle expand more strongly in response to tax increases.

The distributive basis of Figure 2 is not the same as Dupuit's. The levels and slopes of the demand and supply curves in Figure 2 are estimated econometrically or otherwise inferred from market data. So demand (and possibly supply) result from many individual decisions. The only possible rationale is that consumers and producers as groups behave essentially alike. If they didn't, then one would have to go back to differential pricing along the lines of Dupuit's bridge authority to identify beneficiaries by individual willingness-to-pay.

The fact that "economic agents" are assumed to be very similar is at the heart of Utopian capitalism. Does it make sense? Even if it does, why bother to do the computations? One can just as well assert that the gains will be on the order of 0-2%, depending on one's choices of elasticities.

The mainstream response is that the models can provide detail on who gains and loses. That assertion turns out to be tricky. Forces arise at the macro level which can strongly perturb micro level welfare calculations.

As pointed out in Part I for example, tariff reduction will increase the fiscal deficit. Built into the LINKAGE model is the assumption that taxes on household consumption automatically increase to drive the deficit back down to its original level. The negative direct impact of a higher tax on aggregate real consumption is greater than the positive indirect effect of tariff reduction. When the aggregate declines as a consequence, then so must sectoral consumption levels as well, shrinking little triangles. Of course, many other things are going on in a CGE solution which can offset such causal chains, but our simulations with a small model in Part III suggest that they are quite important (especially when elasticities take on more "reasonable" values than the Bank wants to stipulate).

Secondly, the macro level dimensionality of CGE price systems may be low. Although price movements at the sectoral level are affected by specific tariff and subsidy changes, overall

movements in prices can be viewed as being driven by the wage, profit, and exchange rates – a country's system of macro prices has three (or possibly a few more) degrees of freedom.

So macro linkages constrain micro quantity and price responses. At first glance, welfare calculations in a model based on the full GTAP data set seem to amount to sliding around, expanding and contracting big rectangles in 87 x 57 = 4959 diagrams like Figure 2 and figuring out 4959 price changes that will make everything balance out. Given how little we know about data and model specifications, nothing precise can be said about what will happen to the areas of all the little triangles when liberalization makes the big rectangles start to dance. A statement to the effect that a household getting wage income from sector Y in country Z will gain 1.3 cents in consumers' surplus per day forever from tariff liberalization looks nearly meaningless.

The macro complications can make the dance of the rectangles even less predictable. To illustrate we have to bring the exchange rate *e* (*the* key open economy macro price) into the picture. Demand and supply prices are related by a formula such as $P_D = e(1+t)P_S$ in which *t* is the sector's ad-valorem tariff rate. Sector-level price shifts will then be driven by changes in both *t* and *e,* with *e* coming from the macro level. Even if *t* is reduced so that there would presumably be a welfare gain, the change could be offset by an increase or devaluation in *e*.[3]

Also some sectoral prices will fall and others rise in response to differential effects on consumers and producers. Overall, winners in principle should be able to bribe or "compensate" losers so that everyone is better off. In practice compensation rarely if ever occurs, making calculations of improvements or losses in well-being under utopian capitalism even more elusive.

Moreover, we don't live in Utopia. Vested interests have ways to protect themselves. In a "Trade Note" from June 2005, Anderson and Martin assert that "[I]f members succumb to the political temptation to put limits on tariff cuts for the most sensitive farm products, much of the

[3] This is a *summary* of a much more complicated set of price responses emerging from Bank models with their specification based on trade theory, but is one that the modelers accept. According to van der Mensbrugghe (2005) macroeconomic causality "…is identified with two variables – government savings … and foreign capital flows … Both are assumed fixed in any given time period. In the case of the former, direct taxes adjust to meet the fiscal target. In the case of the latter, *the real exchange rate adjusts to match the balance of payments constraint*…" (emphasis added). See van der Mensbrugghe (2005), page 51.

prospective gain from Doha could evaporate. Even if only 2 percent of HS6 agricultural tariff lines in developed countries are classified as sensitive (and 4 percent in developing countries, to incorporate also their "Special Products" demand), and are thereby subject to just a 15 percent tariff cut (as a substitute for the TRQ expansion mentioned in the Framework Agreement), the welfare gains from global agricultural reform would shrink by three-quarters." Small portions of little triangles represent the skimpy welfare gains that would be left.

II.2 Problems in Modeling Trade

In fact, trade calculations in standard models are even more complicated than just indicated. There is a gothic quality to World Bank CGE model architecture. The great cathedrals, after all, have simple floor plans (like Figure 2). But with their arches, towers, gargoyles, spandrels, and stained glass they are immensely complicated structures. Mainstream trade modelers have spent the last three decades adding similar features to basically simple accounting, making their constructs extremely difficult to understand. Much ornamentation comes from their "Armington" specification of foreign trade as described in this section.

To see how the modeling works, we have to delve the details of the trade accounts in the World Bank/GTAP specification. They are based on three traditional distinctions between types of imports. One separates "intermediate" and "final" imports. The former are current production inputs, e.g. imported fertilizer for agriculture. The latter are goods with final uses, e.g. garments for household consumption or machine tools for capital formation.

The second distinction is between "non-competitive" and "competitive" imports, with the idea being that the former are not (and probably cannot) be produced at home, while the latter are (or could be).

Finally, imports may come from intra-regional or extra-regional trading partners.

A first assumption built into the standard models is that many intermediate imports are non-competitive.[4] A second is that final (and possibly some intermediate) imports are

[4] For historical reasons, imported and domestically sourced intermediates are assumed not to substitute for one another in response to price changes, a gargoyle tracing back to Leontief's (1986) use of "fixed coefficients" in his input-output tables.

competitive, to a certain extent. Their treatment as “imperfectly competitive” in standard CGE models raises the further problems in interpreting results mentioned above.

Perfectly competitive imports, with foreign- and home-sourced goods being indistinguishable, don’t fit easily into the world of models. The rational choice would be to buy goods from the cheapest source exclusively so that trading economies in a multi-country multi-commodity world would end up being specialized in the commodities they produce the most cheaply. Such extreme behavior is not observed.

Armington (1969) suggested the trick of making home and foreign goods imperfect substitutes so that if the price of one sort of good goes down more of it will be consumed (and less of the other good will be consumed) but there will not be complete substitution. The strength of the response is gauged by an “elasticity of substitution” discussed at length below. Stanford (1992) gives careful consideration to the pros and cons.

The benefits include the fact that the Armington specification provides a fairly simple, operational model structure for trade. It seems reasonable that a household in the US might decide to buy a typical “American” or “foreign” car.

But there are many drawbacks. The idea that there is *national* product differentiation ignores the fact that characteristics of products are determined by firms, not countries. A Toyota is a Toyota, be it manufactured in Japan or the US. Under the hood of a Ford is a Ford engine, regardless of whether it was assembled in Ontario, Mexico, or Detroit. Much international trade is *intra*-firm, for which the Armington setup is beside the point.

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” start demanding high tech, capital-intensive machinery from abroad because the Armington equations won’t let them.

The implication is that Armington models increase the estimated benefits of liberalization by default because reduction of deadweight losses from tariffs as in Figure 2 is enhanced by cutting back "distortions" due to monopoly power.

Armington as applied in the models under consideration says that domestically produced goods and (tariff-inclusive) intra-regional and extra-regional imports are all imperfect substitutes. Going a step further (and without much empirical backing), hard-core CGE modelers like to sub-divide or "nest" such categories of imports and exports (not to mention production inputs such as land and various labor skill categories, components of the consumption basket, and so on) up to three levels of disaggregation or more to "describe" their substitution possibilities in fine detail. For example, intra- and extra-regional imports might trade off to generate an "overall" import category, which would then substitute with domestic goods.[5] Or maybe the category nesting should go the other way. Spandrels between substitution possibilities and other triangles abound in this line of gothic architecture, making it all the more difficult to penetrate what is going on.

Finally, the Armington technique introduces the fiscal biases mentioned above. To see how, we have to turn to macroeconomics.

II.3 Illustrative SSA/ROW Data

At this point it makes sense to illustrate how the data used in trade models are organized in a social accounting matrix (or SAM), which also serves as an introduction to their macroeconomics.[6] Figure 3 presents a SAM we put together for SSA and ROW using numbers from the extensive GTAP database (more details in Part III). Data manipulation was involved (in part due to deficiencies in the sources) but the matrix is perhaps "representative" of the regions' production and trade patterns early in the present decade. Numbers for two sectors are presented – agriculture and the rest of the economy (or "industry").[7]

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[5] Just how these ideas get built formally into the analysis is taken up below.
[6] Like CGE models themselves, SAMs are fairly ancient. Stone (1966) was the major innovator.
[7] A reader not enthralled by numbers and double entry bookkeeping may want to skip to the description of macro accounting beginning around equation (P) at the end of this section. Our illustrative simulation model further splits the second sector into industry proper and non-traded services.

Figure 3

The fundamental SAM accounting principle is that sums for corresponding rows and columns should be equal – the matrix is a spreadsheet incorporating double entry bookkeeping from the national income and product (NIPA) and flows of funds (FOF) accounts maintained by many countries. The principles will be illustrated by tracing through row and column accounts as we go along.

The lay-out in the main table toward the top is that SSA's accounts are on the left and ROW's on the right. Rows A through E for each region summarize demand and production accounts. Rows E and F give private and government income flows, and rows G and H summarize their financial transactions or flows of funds. Import, export, and foreign aid flows appear in rows I through M. The presence of so many trade rows underlines the complexity of Armington trade accounts.

To begin, row E states the sizes of the two economies. It shows that the sum of wage and profit incomes (or levels of value-added or "factor income") for the agricultural and industrial sectors in SSA are $60.55 billion and $278.99 billion in cells E-1 and E-2 respectively. The total, or "GDP at factor cost" in is $339.54 billion in E-10. SSA's population is on the order of 725 million so that its GDP per capita is about $470 in these data. GDP in ROW is $29,482 billion in E-19 (about 87 times as big as GDP in SSA). With a population of 5,725 billion, its GDP per capita is about $5,150. One region is far more affluent than the other (with by far the biggest share of ROW's GDP in the rich OECD countries).

Labor payments in SSA (not shown in the SAM) are 172.9 so that the labor share of GDP is $172.9 / 339.5$ or 51.7%. "Profits" or all non-labor payments are 161.6. In the model presented below, total profits are set equal to profit rate x capital stock. If the SSA profit rate is 15%, then the capital stock must be $161.6 / 0.15 = 1093.3$ and the capital/output ratio is $1093.3 / 339.5 = 3.22$. These numbers are in the zone of plausibility. In ROW, on the other hand, the labor share is 56.3% which is "too low" by 15-20%. At a profit rate of 10% the capital/output ratio must be 4.37 which is "too high." As in other aspects described below, GTAP macro data for ROW should be taken with a grain of salt.

The economic structures of the two regions differ in other ways. For example, agriculture accounts for 17.8% of GDP in SSA, but only 6.9% in ROW. Consumption levels of agricultural and industrial goods appear in cells B-3 and D-3 for SSA and B-23 and D-23 for ROW respectively. The shares of agriculture in the total are 34% in SSA and 14.5% in ROW, in line with "Engel's Law" which asserts that the share of consumption devoted to food declines as per capita income rises. In two trading economies with such different income levels and structures, the assumptions underlying Utopian capitalism necessarily come into question. It seems unlikely that the "utility levels" underlying the two regions' respective little triangles are anywhere near being comparable.

Next we should look at cost of production and demand accounts.

Column 1 shows that production cost in the SSA agricultural sector is made up of value-added of 60.55 in cell E-1, plus intermediate inputs produced by the sector itself of 35.82 (cell B-1, think of cattle feed grown on the farm etc.), plus intermediates from industry (29.0 in D-1), plus imported intermediates comprising agricultural goods of 2.41 (I-1) and industrial goods of 4.62 (J-1). As discussed below tariff payments are included in import valuations in cells I-1 and J-1. The remaining entry is -2.77 in cell F-1, which is a production subsidy paid by the government. The sum of all these entries is 129.63 in cell N-1, the "gross value of output" in agriculture.

Row B summarizes uses of agricultural products. Total supply is the 129.63 just mentioned plus a batch of "final" imports (gothic details below) of 6.64 for a total of 136.27. Of this, 35.82 goes for agricultural intermediate inputs as mentioned above, 7.3 for intermediate inputs into industry (B-2), 78.84 for private consumption (B-3) and 14.31 for exports (B-5). Row D for industry is similar, except that the sector also supplies capital goods for investment (59.24 in D-6).

Now we turn to foreign trade beginning with Row I for SSA. It summarizes sources and uses of imports of agricultural goods. Including the price distortions due to tariffs they sum to 9.76 (billion dollars) in cell I-10. The middle columns break out the sources. At "world prices" 7.77 come from ROW (cell I-14) and SSA adds 1.28 in tariffs to give a total of 9.05 in I-10. World price

imports from within the region are 0.61 (I-13) to which 0.1 in tariffs are added to give a cost of 0.71 (I-11). Total supply at tariff-ridden prices in I-10 is 9.76 = 9.05 + 0.71.

Of that, intermediate inputs into agriculture take up 2.41 (I-1) and industrial use of imported agricultural intermediates is 0.71 (I-2). The remainder of 6.64 appears in I-7 as the "final" imports mentioned above. To trace their destination we have to look again at rows A and B. The former simply says that final imports are 6.64 (the minus sign in A-7 is a trick to keep the SAM's internal accounting straight – more details below). And in row B, imports plus the gross value of production sum to supply as discussed above.

We are almost at the stage of bringing in macroeconomics. To get there, we first finish describing the external accounts in rows I-M of Figure 3, then turn to income-expenditure accounting, flows of funds, and finally macro balances.

We can continue tracing row I across the SAM. Recall that SSA's world price *imports* of agricultural goods from ROW are 7.77 in cell I-14. From ROW's point of view these foreign sales are *exports*, as represented by the sign flip between cells I-14 and I-15. Intra-regional ROW agricultural exports are -530.84 (I-16) giving total exports of -538.62 in I-19. This is the sum of the entries in row I for ROW. In fact, the row has only one entry (-538.26 in cell I-26). The sum of column 26 is zero, so the sign flips again in cell B-26, showing the export component of the agricultural sector demand-supply balance in ROW. Similar SAM accounting tricks (as proposed by Godley, 1996) are used in column 5 and row K to feed SSA agricultural exports of 14.31 into the ROW agricultural import balance.

There are two main income-expenditure balances for SSA, in row E/column 3 and row F/column 4. Private income is 339.54 in E-10. The same total appears in N-3, and column 3 describes its uses. There is consumption spending of 78.84 on agricultural goods (B-3), and 152.55 on industrial products (D-3). Direct taxes on the private sector are 41.34 (F-3) and it saves 66.81 (G-3). These four entries sum to 339.54. For ROW the direct tax is 4,489.4 (F-23) which is 15.2% of GDP. This share is far "too low." The generous interpretation is that GTAP's number represents direct taxes net of the transfer payments which are a major component of fiscal spending in industrial economies.

SSA government income comes from the direct taxes in F-3 plus tariff receipts (10.26 in F-11) *minus* production subsidies paid to agriculture and industry (-2.77 in F-1 and -6.62 in F-2 respectively), for a total of 42.1 in N-4. Note that tariffs are about a quarter of government net income. One impact of liberalization is to cut tariff receipts, which can be fiscally damaging in the absence of replacement revenues (which, as we will see, World Bank models blithely assume will be forthcoming from increased income taxes).

In most data sets the entries in F-1 and F-2 would be positive to take into account indirect taxes (VAT and so on) net of subsidies, but only the subsidy component is presented in Figure 3. Government uses its income to buy 53.82 of industrial goods (D-4). Like most governments around the world it has negative saving of -11.63 in H-4.

Rows G and H give flows of funds. Standard FOF accounts distinguish between "sources" and "uses" for financial funds which must sum to zero for each "institutional sector" (households, business, government, etc.). Sources are saving and increases in financial liabilities; uses are physical capital formation and acquisitions of financial assets.

The sign convention in Figure 3 is that sources are entered positively and uses negatively. Thus in row G for the private sector its source of funds is saving of 66.81 (G-3). The uses are for investment (-59.24 in G-6, note the sign flip in bringing this number down from D-6) and new lending to the government (-7.58 in G-8). Because 7.58 + 59.24 = 66.82 the row sum is zero (apart from rounding errors). The numbers reflect that fact that private sectors very often save more than they invest, using the surplus to finance a fiscal deficit and/or an external surplus (as occurs for ROW in Figure 3).

The government has to cover its negative saving of -11.63 from other sources. They are the 7.58 it borrows from the private sector (H-8, again with a sign flip between rows G and H) and 4.05 in "aid" from ROW. With appropriate changes of sign, the latter flow traces over to ROW in row M and column 29, where it becomes a use of funds for the ROW government in H-29.

The flows of funds are a skeleton key to the macroeconomics of any open economy model. To open the lock with simple algebra we can consider the accounts of the private sector, government, and the rest of the world.[8]

For the private sector let I = the value (price x quantity) of investment, S = the value of saving, and L = new loans to the government. Then the private flow of funds in row G of the SAM is

$$S - I - L = 0 \quad . \tag{P}$$

It is also true that private sector net borrowing = increase in financial liabilities – increase in financial assets = $I - S$. If you invest more than you save you have to be a net borrower.

For the government, let G = value of expenditure, R = total net revenue (taxes and tariffs less subsidies), and Δ = aid inflow from abroad. Government saving is $R - G$ so the flow of funds (involving only "sources") is

$$(R - G) + L + \Delta = 0 \tag{G}$$

in which, as we have seen for SSA, $R - G < 0$. Government net borrowing is $G - R$, made up of new loans from the private sector and ROW.

SSA runs a trade deficit with imports exceeding exports, and has to finance its external imbalance by borrowing or getting a financial transfer from somewhere. In a two-country world the only possibility is ROW. Net borrowing from the ROW private sector or the government (SSA's foreign lender in the present SAM) is $M - E$ where E = value of SSA exports and M = value of imports.

There are no other net borrowing flows in the system. Because one actor's borrowing must be met by other actors' lending, the sum of net borrowing flows must be zero,

$$(I - S) + (G - R) + (E - M) = 0 \quad . \tag{M}$$

Equation (M) is the basic balance condition in any open economy macro model. Combining it with (P) and (G) and a bit of algebra show that

$$(M - E) - \Delta = 0 \tag{F}$$

[8] Equations (P), (G), (M), and (F) as presented here are restated in somewhat more elaborate form in the next section. The present versions suffice for the discussion at hand.

is the external flow of funds. The SSA trade deficit is covered by ROW's foreign aid.

Evidently, one has to think through the factors determining *L* and Δ. Most World Bank models don't take up such questions in a serious way. They freeze financial transactions between the private sector and the government, setting *L* to an exogenously fixed value. As discussed later, fixed employment sets the saving level so that from the private flow of funds with *L* pre-determined, investment *I* must adjust to equal $S - L$. The models also treat the foreign deficit Δ as pre-determined. If government spending *G* and tariff and subsidy rates are set by policy, the only remaining free variable is *T*. Direct taxes have to adjust endogenously to assure macroeconomic balance in (M) at the economy's exogenously specified levels of employment and foreign aid.

These are peculiar assumptions. Such adept fiscal programming is never observed (let alone over 15 years as assumed in LINKAGE model simulations!). There are many other ways in which economies arrive at macroeconomic balance, as discussed in the following sections.

II.4 Model Specification and Macro Causality in a Closed Economy

The continuo line in neoclassical economics is that prices adjust to clear markets. If only the government didn't impose a tax, that would be the case for the market depicted in Figure 2. However, individual market clearing for *goods* is distinctly *not* the case in CGE models. Rather, changes in prices of *factors* – wages and profit rates – permit the full employment of labor and capital that mainstream models stipulate. Exchange rate changes (interpreted broadly in a model based on trade theory) do the same for the fixed trade deficit. If full employment and a fixed external deficit are not presupposed then even factor price changes retreat to minor roles. Little triangles look even more nebulous than they did a couple of sections ago.

To see how this scenario of largely delinked CGE price and quantity relationships plays out it is simplest first to consider an economy closed to foreign trade. This economy, in fact, is very similar to the one Keynes (1936) described in Chapter 19 of his *General Theory.*[9]

[9] For their own reasons, in their classic presentation of general equilibrium theory Arrow and Hahn (1971) call it a "Leontief economy" featuring cost-based pricing with constant returns to scale.

Analyzing its structure of costs and prices is the best way to understand how a CGE model operates. The first point to note here follows from reading down column 1 of the SAM in Figure 3. In SSA agriculture (and any other productive sector) the value of output is the sum of production costs. In the simplest case one can think just of capital and labor inputs,[10]

$$PX = wL + rK \qquad \text{or} \qquad 1 = \omega(L/X) + \rho(K/X) \quad . \qquad \text{(C)}$$

Production costs equal wages plus profits. "Wages" are the product of the wage rate and employment; "profits" are the profit rate multiplied by the capital stock. In the equation to the left, X is real output, P its price, w the nominal wage, L employment, r the profit rate, and K is capital employed. In the second equation, $\omega = w/P$ and $\rho = r/P$ are the "real" wage and profit rates.[11]

Suppose for the moment that w and r are set by institutional considerations. If the managers running firms more or less minimize costs, their actions will give rise to a behavioral "cost function" tying P to input costs w and r,

$$P = P(w,r) \quad . \qquad \text{(CF)}$$

The firm passes per unit labor and capital costs into the price of its output.

In World Bank models mathematical functions used to represent $P(w,r)$ almost always are given a specific algebraic form involving a "constant elasticity of substitution" (CES).[12] In the present context, the "elasticity" is a parameter indicating how aggressively a firm would use more capital and less labor to produce a given level of output if the factor cost ratio ω/ρ happened to rise. A "high" elasticity (say with a value exceeding unity) means that the L/K ratio would decrease "a lot."

Many other algebraic specifications for cost functions have been proposed, and there is no obvious empirical reason to choose one over the other. A CES function is easy to manipulate mathematically and can be readily extended to permit "nesting" of substitution possibilities. The

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[10] We omit intermediate input flows as in cells A-1, A-2, B-1, and B-2 in Figure 3. Intermediates both add to costs and contribute to demand but not much insight is lost and a lot of notation saved if we leave them out of the discussion.

[11] For the moment it is convenient to value real output and demand flows at the price P. A slightly more general national supply price Z incorporating import costs is introduced below.

[12] The equation is $P(w,r) = (\alpha^{\theta} w^{1-\theta} + \beta^{\theta} r^{1-\theta})^{1/(1-\theta)}$ which mathematicians call a "power mean". That is, P is a fancy non-linear average of w and r with θ as the elasticity of substitution.

elasticity values that Bank modelers select for their Armington import specifications can be controversial, as discussed below.

In a multisectoral framework the price in each sector will be set by such a function. If labor and capital can switch between sectors so that competition leads to uniform wages and profits all around, an individual price P_s *cannot* vary freely to clear the market in its sector *s.* If it did, then that sector's producers would be forced off their cost function which determines P_s from the "macro prices" *w* and *r*. "Market-clearing prices" do not exist at the industry level. All sector-level prices move against one another in response only to wage and profit changes. In a model based on open economy macro, bringing in an Armington-style international trade specification will loosen this price rigidity, but not by very much.

According to a piece of micro theory that Keynes called the "second classical postulate" and that contemporary economists call "Shepherd's Lemma" cost minimization by firms means that input-output ratios for labor and capital will depend on the real factor prices introduced above,[13]

$$L / X = \lambda(\omega, \rho) \qquad \text{and} \qquad K / X = \kappa(\omega, \rho) \ . \qquad \text{(SL)}$$

Although they long ago went on to other concerns, microeconomic theorists put a lot of effort into working out the implications of Shepherd's Lemma at the time when CGE models were being born. Since then, applied modelers have mostly concentrated on adding spandrels and gargoyles fashioned from extensions of equations (CF) and (SL).

Equations (C) through (SL) say that the output price *P* and input-output ratios L / X and K / X depend on *w* and *r* via the real factor prices $\omega = w / P$ and $\rho = r / P$. The same logic goes through with many sectors in which case *X* and *P* are "vectors" or lists of output and price levels.

Now come a few implications (stated at the one-sector level for simplicity):

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[13] Specifically, for a CES cost function the equations are $L / X = (\alpha / \omega)^{\theta}$ and $K / X = (\beta / \rho)^{\theta}$ so that the labor/capital ratio depends on input price ratios only: $L / K = [(\beta / \alpha)(\omega / \rho)]^{-\theta}$. Note how a higher value of θ implies that these ratios respond more strongly to price changes.

Levels of employment of labor *L* and capital *K* will be given by the input coefficients from (SL) multiplied by output levels *X* (if there are many sectors, total employment levels are just the sectoral sums).

Multiplying L / X by X and w and K / X by *X* and *r* gives wage and profit incomes $Y_w = wL$ and $Y_r = rK$ (or sums across sectors).

The value of consumption *PC* is the portion of income flows not taxed away or saved (or paid out as net interest in a more realistic specification). It can be written as

$$PC = (1 - s_w)Y_w + (1 - s_r)Y_r - PT$$

in which *T* is a real " non-distorting lump-sum" direct consumption tax somehow extracted from household spending flows, and s_w and s_r are saving rates from wage and profit income.[14]

Real consumption *C* is

$$C = (1 - s_w)(Y_w / P) + (1 - s_r)(Y_r / P) - T \quad .$$

A change in *T* impacts on *C* one-for-one, a twist that will turn out to be important in understanding LINKAGE fiscal economics.[15]

After taking into account the definitions of wage and profit incomes this second version of the consumption function makes *C* an algebraic function of output *X*: $C = C(X)$. More output leads to more consumption but also to higher nominal ($S = s_w Y_w + s_r Y_r$) and real (S / P) savings as well.

A "material balance" or description of the uses of real output takes the form

$$C(X) + I + G - X = 0 \qquad \text{(MB)}$$

in which *I* is investment in the NIPA sense or "gross fixed capital formation" and *G* is real government spending on goods and services. All sources of effective demand add up to determine output.

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[14] For better or worse, this "consumption function" suppresses all analysis of how firms pass profit income to households via interest, dividends, and capital gains – World Bank models basically don't have any financial transactions. They always set s_w equal to s_r even though data everywhere show that savings rates from profits exceed rates from wages.

[15] LINKAGE treats the endogenous direct tax as proportional to income, adding a "distortion" to lump-sum.

If *I* and *G* are respectively determined by firms' investment decisions and public policy, then equation (MB) can be solved for X. The price system does enter into output determination by influencing levels of real income Y_w / P and Y_r / P but aside from that there is no close linkage between output and prices in a Keynesian economic world.

Before turning to how macroeconomics in this system works out, we should take a quick look at slightly restated versions of the flow of funds accounts discussed at the end of the previous section. Those equations were set up in "value" terms but for clarity they should be rewritten recognizing that *value* is the product of *price* and *quantity*. Anticipating the algebra of Armington imports introduced in the following section, we use national "supply prices" Z and Z^* respectively for SSA and ROW. Definitions of Z and Z^* are presented below.

The private sector flow of funds (P) becomes

$$S - ZI - L = 0 \qquad \text{(P')}$$

in which ZI is the value of real investment at the supply price Z.

The government's flow is

$$(R - ZG) + L + e\Delta^* = 0 \qquad \text{(G')}$$

in which net revenue includes the lump-sum tax ZT (along with tariffs and indirect taxes less subsidies in more complete accounting which will be important below). The foreign aid inflow in terms of the local currency is $\Delta = e\Delta^*$ in which the ROW government is assumed to set the value of aid in terms of its own currency at Δ^* and e is the exchange rate.

The value of SSA exports is ZE. To keep symmetry in notation, let the value of SSA imports be $M = eZ^*E^*$ in which E^* is the real SSA export level.[16] Then the external flow of funds can be written as

$$(eZ^*E^* - ZE) - e\Delta^* = 0 \quad . \qquad \text{(F')}$$

Adding equations (P'), (G') and (F') and switching signs gives

$$(ZI - S) + (ZG - R) + (ZE - eZ^*E^*) = 0 \qquad \text{(M')}$$

[16] For simplicity non-competitive intermediate imports like those in rows I and J of Figure 3 are ignored in the following discussion.

as the overall macro balance.

In a closed economy Keynesian model, the foreign trade term $(ZE - eZ^*E^*)$ should not appear in (M') and the two relevant flows of funds are (P') and (G') with the $e\Delta^*$ term omitted. The demand injections *I* and *G* are pre-determined for the reasons discussed above, and government revenue *R* will be set by tax policy and the level of economic activity. The amount *L* that the private sector lends to the government follows for (G'). That leaves private saving *S* as the only variable which can adjust to give equalities in (P') and (M'). Along with consumption *ZC*, S is an algebraic function of the value of output *ZX.* There are no *direct* linkages between *Z* and *X*. Hence output must vary to make (M') and (P') balance. The saving "leakage" *S* and output *X adjust* to meet the demand injections *ZI* and *ZG.* Real GDP is determined by effective demand although of course changes in tax rates and other policy variables will affect *Z, S,* and *R* with potentially large macro spillovers.

Almost needless to repeat, World Bank/GTAP models incorporate another macro scenario. They stipulate that both labor and capital are fully employed. We need a fixed nominal variable called a *numeraire* to scale the price system, and it is convenient to retain the wage rate *w.* The profit rate *r* can be assumed to adjust to bring the demand for capital into equality with the available supply. In a model in which there are "no black holes" in the accounting (as at present) demand for labor will then equilibrate to supply as well.[17] Real factor prices ω and ρ can be viewed as adjusting to clear their respective markets. The price system will reconfigure accordingly and income levels Y_w and Y_r will be determined from the supply side.

In a slightly restated version of the scenario sketched at the end of section II.3, private saving *S* and government revenue *R* will be determined by tax policy and supply. Private sector lending to the government again follows from (G'). The only variable that can possibly adjust in the private sector flow of funds (P') is real investment *I.* In World Bank (and most neoclassical)

[17] This result follows from "Walras's Law" which states that the price-weighted sum of excess demands (demand minus supply) for all markets in the economy must equal zero. No *single* market can fail to clear.

CGE models investment is determined by saving and fiscal policy. Forces on the supply side dominate macroeconomics.

Is all this realistic or not? For the moment we can beg the question, but it does suggest that one should carry more than one macro causal structure in mind when playing with CGEs. In the literature, causality issues are discussed under the rubric of model "closure." World Bank publications recognize that doubts about specific closures may exist and are explicit about their own models' macro causal schemes. They just don't deign to present alternatives. Concerns about this form of lopsidedness rarely surface in policy consultations with developing countries or in the public debate.[18]

II.5 Open Economy (Armington) Macroeconomics

Now we have to bring in open economy considerations. After describing a model, we take up macroeconomics in a world like the World Bank's and then proceed to Keynes. We have not found a coherent discussion of two-country Armington macro in the literature. What follows should be recognized as our own initial attempt. With one significant exception, the results are not surprising in the context of open economy macro as it existed half a century ago but it makes sense to think them through.

Before getting into the details, though, recall that the LINKAGE/GTAP models are based on international trade theory. There are important differences in the ways that trade theorists and open economy macroeconomists treat price-cost relationships that are worth emphasizing. In trade theory if Z^* is the border price of imports then their tariff-ridden domestic price is stated as $(1+t)Z^*$. Trade enforces some sort of relationship between the domestic price P of goods that compete with imports and $(1+t)Z^*$. Perfect competition means that the relationship would be

$$P = (1+t)Z^* \quad . \qquad \text{(IT)}$$

Armington or other forms of imperfect composition generate other equations tying P to Z^*, as discussed below.

[18] Along with a review of the underlying issues, the not overly felicitous "closure" terminology was added to the CGE literature by Taylor and Lysy (1979). See also Taylor (2004).

The domestic price *P* will also decompose into costs, as in equation (CF) above. Suppose that the wage *w* and profit rate *r* adjust to bring full employment of labor and capital economy-wide so that they are pre-determined as far as the cost function for any sector is concerned. Its price is set by its costs. There is *no* reason to expect *P* from (IT) to come into equality with *P* from (CF) and no mechanism is available to make that happen.

Armington's idea about differentiating traded commodities by country of origin was adopted by CGE modelers (initially from the World Bank, as it turns out) in an attempt to make this problem go away. But an additional step is required. The two-country price system becomes over-determined unless equation (CF) is restated as something like

$$P = P(w, r, q) \qquad \text{(CF')}$$

in which *q* is the cost of an input besides labor and capital that goes into the production of the good whose price is *P.* The input could be "fixed capital" (by sector), "land," some "specific factor" etc. Then the tariff rate and foreign supply price can determine *P* in (IT) which in turn determines *q* in (CF').[19] If *R* is the quantity of the other input there will be an income flow *qR* which will feed into consumption, taxes, etc.

This approach to price-cost structures is the one the Bank adopts in its multisectoral CGEs, which contain a gothic nested plethora of sector-related input prices which adjust to allow determination of final goods prices from foreign prices and tariffs via international trade. The movements of all these input prices are metaphorically viewed as amounting to a shift in the "real exchange rate" (see footnote 3 and further discussion in Part III).

In the open economy macro tradition, the price relationship (IT) is restated as

$$P = e(1 + t)Z^* \qquad \text{(OEM)}$$

in which *e* is *the* exchange rate that brings *P* from (OEM) or an Armington variant into equality with *P* from (CF). The open economy macro approach is the one adopted here, essentially forcing all macro adjustment onto one "conversion factor" which adjusts to link foreign and domestic

[19] There's not much new under the sun. In what is now called a "Ricardo-Viner" specification, Taylor and Black (1974) sidestepped the price over-determination problem by assuming that capital stocks are fixed by sector *i* so that each one has its own profit rate r_i driven via a cost function by an output price $P_i = (1 + t_i)P_i^*$. Also see footnote 22.

prices as opposed to having a number of domestic input prices which can shift. The final outcomes of the two approaches will not differ greatly, and it is easier to think about shifts in one accommodating variable than many.

To see the details we have to examine the supply prices Z and Z^* for SSA and ROW. What is this "supply"? Given accounting like that in Figure 3, supply in SSA must be made up of domestic production and non-intermediate imports.[20] If Z is a price there has to be a corresponding "real" Armington aggregate A of domestic products and imports so that the total value is ZA.

The value of domestic output is PX. From (OEM), after clearing customs imports E^* will be worth $e(1+t)Z^*E^*$. The implication is that the value of domestic supply becomes

$$ZA = PX + e(1+t)Z^*E^* \quad \text{or} \quad 1 = (P/Z)(X/A) + [e(1+t)Z^*/Z](E^*/A). \qquad \text{(A)}$$

We can now apply to (A) the same Shepherd's Lemma bag of tricks employed in connection with (P). A cost function for the supply (or Armington) price Z is[21]

$$Z = Z[P, e(1+t)Z^*] \quad . \qquad \text{(Z)}$$

Just who is minimizing costs to make this equation hold is never made clear. Retailers like Wal-Mart (and its wholesale suppliers)? The Invisible Hand? Be that as it may, there will be a similar equation for Z^* (including a term in Z/e instead of eZ^*). Armington prices in SSA and ROW jointly impact one another. Each also depends via the output price from equation (CF) on its "own" wage and profit rates as well as the exchange rate (and local tariff rates). In SSA, Z is a highly non-linear weighted average of w, r, e, t, and Z^* (and analogously for Z^* in ROW).[22] Cost

[20] The distinction drawn in Figure 3 between "intra-regional" and "extra-regional" imports is suppressed in the following discussion to keep the notation within bounds. We also omit a "constant elasticity of transformation" spandrel separating domestic purchases and exports as sources of demand for total supply.

[21] And again we trot out a CES specification, $Z = \{a^\sigma P^{1-\sigma} + b^\sigma [e(1+t)Z^*]^{1-\sigma}\}^{1/(1-\sigma)}$ which in a more complete formulation would include a term for costs of intra-regional imports as well.

[22] To return to the over-determination problem mentioned above in an Armington context, if we drop the exchange rate and do trade theory, the two countries' supply price equations would boil down to $Z = Z[P(w,r,q),(1+t)Z^*]$ and $Z^* = Z^*[P^*(w^*,r^*,q^*),Z]$. If factor wages and profit rates are fixed, the only way Z and Z^* can adjust to a perturbation of the model is via changes in the "other input" prices q and q^*.

minimization will assure that the "input ratios" X / A and E^* / A depend on their real (Armington) prices.[23]

There is a great deal of discussion in the literature as to whether Bank modelers (not to mention competitors such as Cline, 2004) choose values of Armington elasticities of substitution which are "too high." By making substitution between domestic and imported goods more price-responsive, higher elasticities tend to (i) hold relative prices more stable because quantity responses to price changes are stronger and (ii) add heft to little triangles so that there are greater welfare gains from removing distortions (see section II.1). Further discussion appears below.

The value of the Armington aggregate *ZA* will sum to components of demand as in rows B and D of Figure 3. That is,

$$ZC(X) + ZI + ZG + ZE - ZA = 0 \qquad \text{(MB')}$$

and we can get a "material balance" in terms of real output by dividing through by *Z.*

As just noted, the Armington specification makes the input ratios X / A and E^* / A functions of relative prices. Dividing one expression by the other gives the import/output ratio E^* / X. We can rewrite the external flow of funds balance (F') as

$$eZ^* \mu[P / e(1+t)Z^*]X - Z\mu^*[P^* e / Z(1+t^*)]X^* - e\Delta^* = 0 \qquad \text{(BP)}$$

in which μ and μ^* are price-dependent ratios of imports to output levels in the two countries.[24] Devaluation or an *increase* in the exchange rate *e* will reduce the home import coefficient μ and raise the foreign μ^*.

Now we can do LINKAGE-style open economy macro, assuming that ROW sets the level of aid Δ^* in terms of its own currency and (like the USA) has no policy reaction to shifts in the

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[23] That is, $X / A = (aZ / P)^\sigma$ and $E^* / A = [bZ / e(1+t)Z^*]^\sigma$ with σ as the elasticity of substitution between *X* and E^*.

[24] An explicit formula for μ can be found by dividing the expression for X / A in footnote 23 into the one for E^* / A, and analogously for μ^*.

exchange rate.[25] A natural *numeraire* is the ROW wage rate w^*. As noted above, Bank models render their macroeconomics opaque by suppressing an explicit variable for the exchange rate of each country against a core economy (such as ROW here or the US in practice) and bringing in an array of varying input prices to allow (BP) to balance.

In SSA *w* and *r* are supposed to adjust to make demand equal to supply for labor and capital respectively and r^* is assumed do the same for ROW capital. Shifts in the exchange rate will modify import levels in (BP) so presumably *e* can vary to clear the balance of payments. After all this happens demand for ROW labor will automatically adjust to meet a fixed supply.

An obvious question is what will be the consequences if SSA cuts its tariffs. Presumably imports will increase as μ shifts upward in (BP). There are two channels via which the trade deficit can be brought back to equality with $e\Delta^*$ if *t* is reduced.

One is a fiscal adjustment built into the LINKAGE framework – the only surprising aspect we found in Armington open economy macro. In the present context, net revenue *R* in the government's flow of funds (G') is made up of direct taxes and proceeds from import tariffs,

$$R = ZT + teZ^*E^* \qquad .$$

In a World Bank closure, *R* is fixed because government spending and its new loans from the private sector and ROW are fixed. If the tariff rate *t* is reduced then the real consumption tax *T* must rise to hold *R* constant. As noted above a rise in *T* has a strong *direct* impact by reducing real consumption *C.* Because consumption makes up a large share of aggregate demand, imports will fall as well.[26]

This "effect" does not appear in the standard open economy macro literature and so is worth exploring in a bit more detail. It turns out to be a big gargoyle created by the Armington apparatus.

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[25] In a specification based on trade theory, *e* would not appear in (BP) and the supply price (or prices in a multisectoral set-up) *Z* would be the adjusting variable(s), via shifts in the output price(s) *P* which would map into endogenous input price(s) *q* in (CF').

[26] Reducing export or production subsidies would have the opposite effect. Government net revenue would rise meaning that direct taxes would fall to hold *R* constant. As it turns out, the LINKAGE closure with an endogenous lump-sum tax resembles Johansen's (1960). But he was using his model for medium term sectoral growth projections and did not get distracted by the fiscal twists of tariff and subsidy changes (and certainly did not utilize the Armington apparatus).

With no Armington complications, the traditional story is that a minimalist government puts a tariff on imports and then gives the returns back to households as an income transfer. The value of output is *PX*, which also equals household income. If there is no government spending on goods and services and zero investment, then commodity market equilibrium means that output goes to consumption and exports, or

$$PX = PC + PE \quad .$$

The trade balance is

$$e\Delta^* = eZ^*E^* - PE \quad .$$

Substituting for *PE* in the equation for *PX* and rearranging gives

$$PC + eZ^*E^* = PX + e\Delta^* \quad . \qquad \text{(T)}$$

The value of consumption of domestic goods plus imports at world prices equals the value of output plus the foreign transfer.

An import tariff which is refunded has no *income* effect on demand. Bringing in the tariff/transfer procedure described above, it will also be true that

$$PC + e(1+t)Z^*E^* = PX + etZ^*E^* + e\Delta^* \quad .$$

The term etZ^*E^* cancels on both sides, or the tariff only induces substitution responses between real consumption of domestic goods *C* and imports E^*.

Now bring in Armington as in the LINKAGE specification, still assuming that the government only levies an import tariff. Working with an Armington supply aggregate *A* and price *Z*, the goods and trade balances in current prices become

$$ZA = ZC + ZE$$

and

$$e\Delta^* = eZ^*E^* - ZE$$

respectively.

From (A) above the Armington cost breakdown is

$$ZA = PX + e(1+t)Z^*E^* \quad .$$

The key point is that in this decomposition the tariff cost $e(1+t)Z^*$ is just one component of the Armington price *Z.* This does not happen with *P* from equation (OEM) in the traditional story.

Combining the equations gives

$$ZC = PX + etZ^*E^* + e\Delta^* \quad . \qquad \text{(L)}$$

Using "hat calculus" tricks (Taylor, 2004, pp. 54-55) in (A) one can show that the partial derivative of the term on the left in (L) with respect to *t* is $(C/A)eZ^*E^*$ while the partial on the right is eZ^*E^*. Unless all of the Armington aggregate *A* is used for real consumption *C*, the derivative on the left will be less than the one on the right. The immediate implication is that the ratio C/A will have to fall to maintain equality in (L) if *t* is reduced (regardless of any substitution responses of C/A to the price ratio $e(1+t)Z^*/P$). The only way this can happen is for aggregate real consumption to decline.

To view this income effect from another angle, we can bring in government spending *ZG* and the lump-sum tax *ZT* but still assume zero investment. The fiscal balance is

$$ZT + et^*Z^*E^* + e\Delta^* + sPX = ZG$$

with *s* as the private saving rate. Substituting into (L) gives an alternative expression

$$ZC = (1-s)PX - ZT \qquad \text{(L')}$$

for the impact of tariffs on consumption, sketched above and in the discussion in Part III.

Again, only the fraction C/A of tariff proceeds etZ^*E^* contributes to the value of aggregate consumption ZC, while all of offsetting direct taxes *ZT* are subtracted from it. Presumably on the basis of the traditional open economy scenario, people using the Armington specification have ignored such effects. In a multisectoral context, they are bound to introduce biases of unknown direction and magnitude into standard benefit estimates from any form of liberalization. Little triangles expand and contract unpredictably.

Besides this fiscal complication, the other adjustment that can shift μ back downward is an increase in *e* which will also induce the ROW import coefficient μ^* to rise. If the two responses are strong enough, external balance for a given transfer Δ^* will be restored. The Bank

likes to emphasize how liberalization will rearrange trade flows in the direction of exports through the induced devaluation. Of course, this result is already built into their model.

Bank models basically adopt the "elasticities" approach to balance of payments adjustment introduced before WWII and at the height of its popularity around 50 years ago. This literature ignored the fiscal effect (which is, after all, a matter of "absorption" as discussed below). Operating by itself, the exchange rate can rebalance (BP) if a "Marshall-Lerner" condition is satisfied. Because of the cross-dependence of Z and Z^* discussed above, a formal statement in the present set-up is incredibly messy but the lead terms resemble those in the usual textbook versions. The elasticities of substitution σ and σ^* between domestic output and imports in the SSA and ROW Armington aggregates A and A^* are the key parameters. In the open economy macroeconomics tradition such elasticities are usually presumed to take values in the range of one to three. Bank models often peg them in the range of three to six and other authors put them even higher.

Perhaps being overly cynical, we can think of two justifications. One is that, as we have seen, higher elasticities tend to enhance welfare gains from eliminating distortions. The other is that in equation (BP) a devaluation or increase in the exchange rate e will reduce the world price Z / e of SSA exports and shift the terms of trade adversely. There are many possible offsets in a multi-sectoral model. Armington prices Z and Z^* interact with one another and there will be movements in relative prices across sectors. Nevertheless, the shift in the terms of trade against SSA will be *stronger*, the *lower* is ROW's demand elasticity η^* because the demand response to devaluation will be weaker.

So higher elasticities attenuate or even reverse adverse shifts in the terms of trade in response to devaluation. The problem in the context of reducing protection for agriculture is that price elasticities of demand for products from the sector are *low* (indeed often estimated to be less than one). This is the first lesson that agricultural politicians and economists learn. The implication is that it makes sense to support agricultural prices because their downward excursions in response to transient upswings in supply or downswings in demand are likely to be

very large. In the algebra of (BP) adverse shifts in the agricultural terms of trade in response to tariff reductions look almost inevitable for usually accepted elasticity values. Is that why World Bank economists prefer to boost their numbers for η^* from something like 0.5 to 5?[27]

A more Keynesian story about the trade balance that also emerged just after WWII emphasizes changes in "absorption" of external perturbations. For a given exchange rate, movements in the level of economic activity, foreign transfers etc. will reallocate production flows and incomes.

It is worthwhile to think through scenarios with an endogenous fiscal deficit so that the Bank's odd treatment of household taxes does not apply. Then, because tariff reduction cuts prices and eats into government net revenue it might be expected to stimulate aggregate demand in addition to raising the import coefficient. Various adjustments can ensue. We can trace through examples for SSA, assuming that feedback effects onto ROW are relatively weak.

One possibility would be an endogenous post-liberalization increase in ROW's new loans to SSA in an example of "aid-for-trade". In ROW, higher taxes feeding into government revenue or increased government borrowing from the private sector could let capital flows become an accommodating variable responding to a reduction in SSA tariffs. ROW would "finance" SSA's reduced exports and higher imports resulting from liberalization with the exchange rate held constant. From an historical perspective, growing post-liberalization foreign trade deficits accompanied by rising debt levels in a developing country are not an unlikely adjustment scenario. It is, however, excluded by the assumptions about macroeconomic causality made at the World Bank.

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[27] Dimaran et.al (2002) from GTAP quote Jomini, et. al. (1991) to the effect that their preferred ".... SALTER settings [of elasticity values] represent a compromise between econometric evidence and prior belief. A search of the econometric literature indicated that these elasticities are relatively low. On prior belief, it is generally believed that the terms of trade effects of commercial policy changes are generally quite weak. Such weak terms of trade effects imply that the source substitution elasticities are relatively high. The SALTER settings adopted here, thus, represent a compromise: the elasticities are generally higher than that indicated by the econometric literature, but still low enough to generate significant terms of trade effects."

Alternatively, the SSA exchange, profit, and wage rates could be held constant and investment could be exogenous. Then the SSA external deficit, government borrowing, and output could all change endogenously in a pure “absorption” scenario.

Illustrative numbers are attached to pure World Bank and absorption closures in Part III.

Part III: Simulations

In this part we discuss our demonstration CGE model and its simulation results. We begin with the specification and compare it to the World Bank's LINKAGE model. Secondly, we discuss various closure rules. Finally, we analyze simulation results of selected liberalization scenarios under two closures.

III.1 Aim and Scope

This section summarizes the aim and scope of our model as well as its major differences with LINKAGE. We had the following goals in mind: The model should stylize the CGE approach to trade and be capable of providing policy insights with regard to the Doha process. To allow for a critique of the LINKAGE framework, the model is based on broadly the same assumptions and theoretical constructs. Furthermore, in order to contrast the World Bank's model with alternatives, we want to be able to change some of those assumptions.[28]

In the following paragraphs we contrast the two models by juxtaposing excerpts from the Bank's latest technical reference document[29] with brief sketches of our set-up.

"The Linkage Model is a global dynamic computable general equilibrium model (CGE) with a 2001 base year. [...] A recursive framework is used to drive dynamics, with savings-led investment and productivity. The model incorporates adjustment costs in capital markets and trade-responsive endogenous productivity."

First of all, the model presented herein is static, and computes once-off effects of liberalization and other perturbations to the data built into the base-year SAM. The Bank's model is also essentially static, but it is run over a number of periods ("years") to generate a simulacrum

[28] The World Bank's model in fact allows for these changes, but usually neither different simulation results nor possibly differing policy recommendations are reported.
[29] See the abstract in van der Mensbrugghe (2005), hereafter vdM.

of dynamic change. For example, tariffs are usually phased out over several years to leave room for adjustments in domestic policies as well as agents' behavior.

More importantly, the World Bank adopts the assumption that an increasing export/output ratio (say, in response to liberalization with a positive export response that is built into Bank models) raises a sector's labor productivity with the strength of the response depending on a pre-set elasticity, as usual. This idea is as old as trade theory: When autarchy breaks down in a Ricardian world in which comparative advantage determines trade patterns, the resulting specialization has positive productivity effects. In the classic example, Portugal and England increase output of wine and cloth for given factors and technology, as each concentrates on the good it can produce more cheaply.

While most economists agree that such things can happen, it is by no means undisputed that there are positive linkages to growth and welfare. Given the broad trends in the manufacturing sector in the US and its imports of manufactures for example, one might argue that increased trade eroded the manufacturing base in the U.S. and consequently forced industries to specialize and "move up the value chain," consistent with productivity increases on the one hand but with negative employment, distributive, and welfare effects on the other (there are of course many similar stories in semi-industrialized economies like Brazil). In its Doha models, the Bank's treatment of this issue is mechanical and ad hoc, so we chose not to pursue it.

"It features three production archetypes – crops, livestock, and other – a full range of tax instruments, price markups, multiple labor skills, vintage capital, and energy as an input combined with capital ... and incorporates 87 countries/regions, and 57 sectors" (vdM, p.1).

A principal difference between LINKAGE and our model is that we attempt to keep things simple. The Bank's model has about 4500 equations. This level of detail is most utterly impressive, but it makes the workings of the machine impossible to understand. Our model has "only" 125 equations. This reduction implies that we aggregate sectors, factors and regions: We use three sectors (agriculture, manufactures and services), not 57, two factors (labor and capital),

not five, and two regions (Sub-Saharan Africa and the rest of the world) instead of 87 as in LINKAGE.

There are certainly important benefits from higher dimensionality. A global reduction in rice tariffs has a very different impact on Japan than Switzerland. Our model cannot address this issue, as rice prices and production are subsumed in the broad agricultural sector and, moreover, Japan and Switzerland appear to be the same country. Similarly, the ROW region comprises countries such as Indonesia and France. The Indonesian agricultural sector enters importantly into GDP and employment, whereas the most prominent aspect of France's agriculture (leaving aside the 350 cheeses[30] and sundry other products beloved of trade negotiators which neither LINKAGE nor our model can consider) is the high level of protection it enjoys under Europe's Common Agricultural Policy.

The advantage of the simplifications is that our model remains at least to some extent tractable. It also allows us to focus on macroeconomic forces which drive micro results, an aspect of the LINKAGE specification which the Bank's publications elide. Our choice of regions stylizes trade between a large, rich and a smaller, poor region and directly addresses the Doha process with its focus on development concerns as well as the pivotal areas of negotiations, agriculture vs. NAMA.

"Trade is modeled using nested Armington and production transformation structures to determine bilateral trade flows".

Despite all the problems inherent in the Armington approach, our model is based broadly on the same principles as LINKAGE.[31] On the production side, intermediates enter with fixed coefficients. Their "Leontief technology" presupposes that intermediate inputs, e.g. steel and chips going into machine tools, are required in constant proportions. If its price increases, one

[30] The count according to Google seems to have risen since Charles deGaulle's famous question in *Newsweek* in 1962: "How can anyone govern a nation that has two hundred and forty-six different kinds of cheese?"
[31] The features discussed are common to the overwhelming majority of global trade models.

input cannot be partially replaced by another. Imported intermediates are subject to the same assumption which has become traditional in CGE modeling.

Labor and capital, however, trade off against one another according to the ubiquitous CES specification. Consistent with standard microeconomic theory, these functions are derived from a unit cost function that determines the overall price level, which is in turn dual to a production function. The Armington trade structure applies the same principles to determine import and export ratios as well as international prices.

"In its standard version, it is a neo-classical model with both factor and goods market clearing.... Closure is identified with two variables – government savings and foreign capital flows. Both are assumed fixed in any given time period. In the case of the former, direct taxes adjust to meet the fiscal target. In the case of the latter, the real exchange rate adjusts to match the balance of payments constraint" (vdM, p. 51).

As pointed out in Parts I and II, the Bank's reference to the exchange rate is disingenuous. LINKAGE does not include exchange rate variables per se, and "exchange rate changes" are a metaphor for thousands of individual price adjustments which are impossible to think through in detail. Our specification incorporates the exchange rate explicitly.

Also, there is no space for unemployment in the version of the Bank's model described in the quote, which implies that whatever outcomes trade liberalization may have, by assumption they do not include lack of jobs or underutilization of capital. Bank models *can* address issues of employment (or shifts in the trade balance) but usually the modeling department *chooses* not to do so.[32]

Contrary to the World Bank, we report and compare simulation results with and without a full-employment assumption. Not only employment, but also the current account and the government balance are important indicators of macroeconomic performance. The World Bank freezes these three major variables out of the analysis and focuses almost exclusively on welfare

[32] LINKAGE papers usually refer to full (or fixed) employment in a footnote or abstract, but neither discuss it in detail nor attempt to justify the assumption.

measures. More realistically, which of these variables is (or are) endogenous and which exogenous depends on the specific closure assumptions made by the modeler.

A few more details should be mentioned: All of the government's expenditure is assumed to go to the services sector. Investment demand is only for industrial goods. Intermediate imports are assumed to be exclusively intra-regional in the developed world, but exclusively extra-regional in SSA. The data appear to allow for such a simplification, as, first, the overwhelming part of imports to SSA comes from outside the region and, secondly, it is likely that intermediates such as industrial goods and machinery have to be imported from the northern hemisphere.

Lastly, an important difference between our model and the most recent LINKAGE is the data set used. The World Bank collaborates closely with GTAP at Purdue University[33], which provides an extensive data set for global trade analysis. The most recent version – GTAP 6 (2005) – includes important updates of the protection data base. Liberalization results of the Uruguay Round are taken into account. Probably more importantly, preferential trade agreements, bilateral tariffs, and non-tariff barriers are built in.[34] In contrast, our base-year data stems from the previous version of GTAP, which is freely available. GTAP 5[35] has a 1997 base-year and does not fully account for bilateral tariffs and other special agreements. We updated tariff rates based on a recent World Bank publication[36], but otherwise kept with the older GTAP data set.

Do we lose important insights using an “outdated” version? The goal of our analysis is to show how a plausible model hangs together, rather than compete with the World Bank’s level of detail or timeliness. The 1997 data set, aggregated in two regions, shows a “rich” region trading with a “poor” region just as GTAP 6. However, on average we would expect full liberalization benefits to be greater than in the World Bank’s recent simulations, because the Uruguay potential had not been fully realized by 1997.

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[33] Global Trade Analysis Project, see https://www.gtap.agecon.purdue.edu/
[34] Ackerman (2005) discusses how changes in the underlying data sets dramatically altered simulation outcomes. See also FAO (2005).
[35] For an extensive documentation of the database, see https://www.gtap.agecon.purdue.edu/databases/archives/v5/v5_doco.asp
[36] Anderson et al. (2005), Working Paper 3607, Table 1, page 27

In summary, the model presented here attempts to replicate the structures of the World Bank's model, simplifying and aggregating along the way, but extending the analysis to a broader set of important variables. Different closure rules are described in the next section.

III.2 Closure Rules

As mentioned above, and in contrast to the World Bank, we apply different closure rules.[37] Before describing these different "regimes" in a bit more detail, it makes sense to motivate our simulation strategy. Economic theory implies causation in the sense that one variable in a formal model drives another one. In the labor market context discussed above, causation runs either from employment to wages or from wages to employment. If the employment is given – and "full" – the wage is determined from the functional relationship between the two, or vice versa. Thus, the modeler has to make an *a priori* decision about which variable is endogenous to the model. If employment, the current account, and the government deficit are exogenous and remain unchanged, the model will generate changes in the wage, exchange rate, and taxes but will not be able to provide policy recommendations about rather important *quantity* macro variables.

On the other hand, in certain situations it is perfectly reasonable to assume, for example, a fixed current account. If a model addresses the short run and focuses on, say, Germany – a country with a persistent and relatively stable trade surplus – the current account might not be the major concern of the policies in question. However, many countries subject to the Doha negotiations are prone to high current account deficits; in fact, high deficits are characteristic of recent financial crises in developing countries. To put it carefully, there is no reason not to consider possible effects of liberalization on the current account.

It is unnecessary to claim that *any* closure assumption reflects the "true" direction of causation. Applied economists are well aware that certain models and their assumptions fit certain situations, periods, and countries and might not add insights in other circumstances. For a

[37] Recall from previous discussion that “closure” is CGE jargon for assigning causality in a model. The practice often boils down to deciding which variables should be exogenous or endogenous (or which equations included or excluded) to make sure the model is “closed” or has a solution like a typical problem from high school algebra.

model on a global scale and an issue as hotly debated as the Doha Round it simply seems prudent to look at the issues from different perspectives. Suppose empirical research could show (or have shown) that the exchange rate is a highly flexible international price that adjusts to guarantee balanced trade with 50% probability. Should policy analysis not address the other 50% as well?

Thus, we will outline a few selected scenarios and subsequently discuss our simulation results, with the aims to highlight limitations of the World Bank's modeling strategy as well as to shed light on the current negotiations at the WTO.

At the macroeconomic level in either region, three key flows of funds balances have to be satisfied and two factor markets have to be described, which gives 32 different closure combinations between the private balance (savings and investment), the public balance (government spending and revenue), the foreign balance (current account and the exchange rate), and the factor markets (capital, labor, and profit and wage rate, respectively). We will limit ourselves to two exemplary closures: The *Bank's closure* and an *absorption closure*. The macroeconomics of various closure rules has been discussed in Parts I and II. Here we just briefly review the key elements. See Figure 4.

Figure 4

The Bank's closure works along the lines of the elasticities approach to the balance of payments (as extended by fiscal effects discussed in Parts I and II and illustrated below). The government deficit, the current account, and employment levels are exogenous. Simulation results under these assumptions do not allow one to draw conclusions about the likely future behavior of these variables. They are set in stone at their base year levels, so that any – however drastic – changes affect neither the public and foreign deficits nor the (un)employment rate. Consistent with neoclassical theory, adjustment is mainly carried out by variation of prices. As will be seen, however, the price changes often dance to macroeconomic and not micro tunes.

Besides goods prices, factor prices (wage rate and profit rate) and the exchange rate shift so that the aforementioned constraints are satisfied. If the government deficit is

predetermined, the government is not able to finance expenditure by increased borrowing. Tariff and subsidy rates are simulation parameters and prices adjust endogenously, hence the only variable that can adjust in the government balance is the household consumption tax.[38] In the private balance, investment adjusts to savings and, lastly, the exchange rate adjusts so that the current account stays constant. As emphasized in Part II the exchange rate in our set-up is a variable that appears explicitly instead of being a metaphor.

With regard to factor markets, full employment rules. In the Bank's closure the totals of employed labor and capital in the two economies are assumed to be constant. At the sectoral level, however, labor-capital ratios can (and must) shift in any new solution.

Our absorption closure presents the natural antithesis to the Bank's closure. In all macroeconomic balances, causality assumptions are reversed:

Taxes on households are held constant so that the government deficit adjusts to finance expenditure and absorb the revenue reduction when tariffs are cut. Government borrowing moves up and down in any functioning economy, even when it is hypothetically constrained by IMF conditionalities or Maastricht accords. Letting it play its proper role in a model simulation is simple common sense.

Fixing the exchange rate leaves the current account as an adjusting variable. It permits macroeconomic "absorption" of shifting import and export *quantities*, instead of an "elastic" adjustment of trade flows to international *prices*.

In the private balance, investment is predetermined. This view follows Keynesian theory in which entrepreneurs decide about the investment projects according to long-term expectations and *animal spirits* rather than automatically channeling available savings flows into physical investment.

Lastly, in this exercise we abandon the full employment assumption. Employment levels of both capital and labor are variable, and wage and profit rate are fixed. As in the Bank's closure,

[38] We will see below how differently this assumption plays out in the "rich" and "poor" region: In our developing country, either taxes jump up or government spending contracts dramatically in order to match the constraint on the deficit.

workers and capital can freely move from sector to sector, but may end up under- or over-employed. Demand changes *can* have an impact on employment.

III.3 Results

The World Bank usually contrasts a model's results under complete liberalization with some "likely" Doha scenario which would take into account political realities, the current state of the negotiations, and the principles underlying them. The developing world would presumably allow more non-agricultural market access for firms from the North, and the developed world would lower agricultural protection by removing subsidies for agro-exporters as well as tariffs on imports. Given the development emphasis of the Doha round and various "special treatment" clauses, SSA would be required to cut tariffs by less then ROW. Overall, tariffs and subsidies would be reduced but not eliminated.[39]

We take up such comparisons below, but start out with a pair of more simple liberalization exercises to trace through the effects of removing just one "distortion" on factor returns, prices, welfare, and other important indicators. Full liberalization involves complete removal of all subsidies and tariffs.

Sensitivity analysis is an important dimension of a complete model description. CGE models are fed a banquet of parameters that at best come from econometric analysis, but often from prior belief and (more or less) educated judgments on the part of the modeler. It is indispensable to investigate the effects of changes of parameters on results and the model's policy recommendations. Parameter values derived from a mixture of econometrics – itself often not to trusted – and a modeler's considered opinions could quickly render conclusions irrelevant if they are not robust to "reasonable" changes.

The most important – and controversial – parameters in LINKAGE/GTAP-style trade models are the Armington elasticities. As discussed in Parts I and II, the World Bank has been criticized for using elasticity values that are "too high." Higher elasticities improve the

[39] For fairly comprehensive overviews of the Doha issues and negotiations, see http://www.ictsd.org/ or http://www.fao.org/trade/policy_en.asp.

responsiveness of trade flows to price changes, which in turn requires less adjustment in other macroeconomic variables. We will focus on Armington elasticity values.[40]

Limiting the analysis to "only" three liberalization scenarios, three closure rules and, say, three different regimes of trade elasticities already gives a wide range of combinations to discuss. The difference between our and the World Bank's modeling strategies becomes obvious. Instead of including scores of regions and sectors we attempt to describe broad patterns of results from different theoretical perspectives. Certainly, estimating regional and sectoral changes in detail is invaluable for policy makers, but given the task at hand it seems unlikely that additional insights could be gained from greater disaggregation. Our simulation strategy is summarized in Figure 5.

Figure 5 here

SSA Agricultural Tariff Elimination (Bank's closure)

The baseline configuration features trade elasticities of a lower average magnitude with stronger econometric support than the ones commonly used in LINKAGE or GTAP. Completely removing, in a first exercise, the external agricultural tariff in the developing region – the tariff SSA applies to agricultural imports from ROW – and applying the Bank's closure rules has small, but *negative* effects on welfare in SSA.

That the effects are *small* is not surprising in light of the fact that SSA's GDP is around 1.1% of ROW's (see the discussion of Figure 3 in Part II). A change in just one tariff in a small open economy has effects on that economy, but triggers close to zero response in the larger partner.[41]

In any scenario prices and quantities must be considered separately. Given the functional relationships among tariffs, prices, and wage and profit rates, we can trace a chain of causation in the results: a tariff decrease lowers the agricultural sector supply price *Z* in the Armington cost function and the output price *P* in the cost decomposition of domestic output in SSA. Real value

[40] We also examined different degrees of factor substitutability, but found little effect on the overall results.

[41] Often, open economy macroeconomics is undertaken under a "small open economy" assumption, meaning that there are no repercussions of policy changes in the economy under study on the rest of the world. As discussed in Part I, global CGE-trade models apply to the whole world, and as we will see below there are effects on the large economy in other scenarios.

added *V* decreases slightly and factor returns fall, which in turn pull the value-added price *Q* and the overall price level down.

Why does real value added decline? Looking at *V* takes us to quantity variables. The change in relative prices due to the tariff decrease increases SSA demand for agricultural imports. In this particular simulation, real imports rise by more than 14%, whereas the average change in trade flows hovers at about 1%.[42] Consumer households substitute Iowa maize for the local product in their mealy-meal, so that domestic agriculture faces an adverse shift in demand. Real output in SSA agriculture declines by about one percentage point[43], because the adverse demand shock is *not* neutralized by a positive shift in export demand. As we will see in other simulations this problem disappears with higher trade elasticities. In the present case, relative price changes induce demand shifts that translate into negative GDP growth.

The contraction of value added is a consequence of the core fiscal adjustment (noted repeatedly above) in the Bank's closure. The SSA government is constrained to borrow constant amounts from the private sector and ROW but receives less tariff revenue due to liberalization. Its only possible recourse in a LINKAGE world is to raise taxes on household income to balance its flow of funds. Raising taxes crowds out private consumption, which provides the basis for the little triangle welfare calculations commonly applied. Two effects contribute to a decrease in welfare: the decline in value added tightens the private sector budget constraint and consequently diminished consumption levels are further stifled by increased taxes. The welfare losses are small – a third of a percentage point – and other macroeconomic performance indicators – employment, current account, fiscal deficit – are constant by assumption.

SSA Industrial Tariff Elimination (Absorption closure)

Tracing through a similar exercise exemplifies how adjustment works in the absorption closure. This time we look at the effects of removing SSA's tariff on industrial imports. Again, trade elasticities are assumed to be "normal".

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[42] Except for the outlier – agricultural imports from ROW to SSA – SSA exports increase by 1% and other imports decrease by roughly 1%, as the relative import price of agricultural product improves. Furthermore, the change in agricultural imports is approximately inversely proportional to the change in the tariff, which was 16.5% on exports from ROW to SSA.

[43] Due to the price decrease the decrease in nominal terms is larger.

Recall that macro causality now is along Keynesian lines, where quantities instead of prices bear the weight of adjustment. The wage, profit, and exchange rates are fixed and the current account and government deficit are endogenous. As before, we analyze price and quantity changes. The former are essentially the same – as to be expected since we did not change the *model structure*. The industrial supply price *Z* decreases in response to the tariff removal. Factor prices are exogenous, so that the price of value-added *Q* cannot change. The difference with the previous story is that domestic output is not forced to contract if the export response lacks strength. In fact, because the foreign deficit is free to rise, neither exports nor GDP need move to balance an import surge.

The simulation results are clear: the current account worsens tremendously with rising imports resulting from the shift in the relative prices of domestic and foreign manufactures. In order to satisfy its flow of funds constraint and match the loss in tariff revenue, the government (now free to borrow more from the private sector while holding income taxes constant) increases its deficit spending.

Manufactures from the developed world are important inputs into the Sub-Saharan economy. The fall in input costs therefore increases output, at least in the agricultural and service sectors. Demand for manufactures themselves shifts towards foreign products, and real domestic output in the industrial sector contracts. Still, the overall effects on economic activity are positive. Because the government does not raise taxes, real output and value-added growth lead to an increase in consumption. SSA enjoys welfare increases, here about 1.3% of GDP. Employment is proportional to value-added, so that expansion in this exercise leads to higher demand for labor and the utilization of capital.

Sadly, the picture is not as rosy as might appear from the last few lines.[44] Little triangle measures of welfare gains, derived from "first principles",[45] have the advantage of being widely accepted and comparable (under the rather stringent assumptions of Utopian capitalism), but really only make sense if other macroeconomic indicators are held constant by assumption.

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[44] The following points suggest that if the economy is not artificially held at full employment, a CGE model is probably better suited to analyze the short term than the long term questions.
[45] See Varian (1992). We report both Equivalent and Compensating Variation.

Looking at the jumps in both foreign and public deficits,[46] one can identify the risks faced by this developing economy. Chronic indebtedness, debt crises, capital flight, and political instability are only some of the problems it would confront in the not too distant future.

Fiscal Implications of Output Subsidy and Import Tariff Elimination

We are almost ready to discuss simulations of full liberalization. All tariffs, output, and export subsidies are removed. In the World Bank's model, this implies that any distortion as shown in Figure 2 is eliminated, and all those roughly 5000 little triangles are freed to enlarge global welfare. In our model, the export subsidy on manufacturing exports, the output subsidies in all three sectors, and the tariffs on the two traded goods are reduced to zero. Let's start by looking at results in the Bank's closure.[47]

Total employment, the current account, and the government deficit remain, of course, unchanged. Before getting into details of the full liberalization it is helpful to disentangle the effects of full output subsidy removal on one hand and full tariff removal on the other. Fiscal effects again dominate the scene.

The output subsidy makes up a large part of the total expenditures of the government, and saving those costs translates into lower taxes on households because the fiscal deficit and government consumption are fixed. Ceteris paribus, lower taxes increase disposable income and thereby consumption, which leads to potentially hefty increases in welfare.[48] Tariff liberalization, on the contrary, decreases fiscal revenue instead of expenditure and forces the government to raise taxes, which crowd out consumption and reduce welfare. These are *macro* effects. Nevertheless, they go a long way toward determining the characteristics of the Bank's microeconomically oriented closure.

Evidently, welfare consequences of full liberalization in the Bank's closure depend not only on trade elasticities, but also on the initial height of tariffs (for government revenue) and subsidies (for government expenditures). Generously interpreted, the welfare result following

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[46] In this simulation, the external gap more than doubles, the public deficit increases by 60%.
[47] As above, we discuss simulations with reasonable trade elasticities. Sensitivity analysis of simulations with Armington elasticities of the magnitude used in LINKAGE/ GTAP is presented below.
[48] Eliminating only output subsidies increases welfare by more than 10% and 5% in SSA and ROW, respectively.

subsidy removal could be interpreted as an efficiency gain, in the sense that producers employ resources in the most productive way instead of being misled by “wrong” price signals from the subsidies.

Less generously, and probably more realistically, one could interpret the welfare increase as the model’s inability to capture the socio-economic adjustment costs that come with such a policy change. American and European trade negotiators do not block major modifications to their agricultural protection schemes because they disdain textbook economic efficiency (assuming they understand the concept!). Rather, a few million farmers in Europe and thousands of agribusiness enterprises in the US would fail if their subsidies were slashed. Extreme, politically damaging food price jumps could easily ensue, and the erstwhile farmers and employees would not smoothly metamorphose into software programmers. World Bank analysts apparently deem such metamorphosis possible. The equivalent assumption about businesses would probably be that owners have hedged any potential losses.

To summarize, full output subsidy removal in the Bank’s closure has strongly positive welfare effects for the reasons discussed above. “Money” freed from the government’s intervening, visible hand stimulates demand and real output increases. Import growth is strong, but high exports balance the current account due to a robust devaluation of the SSA currency. Prices *increase* in SSA, but *decrease* (along with factor returns) in ROW.

Radical tariff elimination, on the other hand, triggers only small price changes. Composite supply increases due to the growth in trade, but domestic output decreases across the board. As import prices fall, demand for foreign product rises relative to domestic product; the consumption crunch following the rise in taxes consequently depresses domestic real output.

Full Liberalization with the Bank’s Closure

Having sorted these things out, we can return to the initial question: What effects does full liberalization have in the Bank’s closure? The leftmost bars in Figure 6 show the welfare results with reasonable elasticities in both SSA and ROW, the dashed line indicates the average

Armington elasticity. SSA loses slightly more than half a percentage point[49] of GDP, ROW gains *circa* 3%. If our base year data had featured higher subsidy and lower tariff rates, Sub-Saharan Africa could have very well shown higher – i.e. positive – welfare gains. ROW's welfare gains are due to the fact that subsidies were high.

Figure 6 here

Full Liberalization under the Absorption Closure

Let's look at full liberalization in the absorption closure, with results summarized in Figure 7. As above, it helps to analyze subsidy and tariff liberalization separately. Removing all subsidies in this rather Keynesian economy has interesting effects. Subsidy elimination triggers a heavy contraction of demand as the government saves the funds it previously spent on subsidies to reduce its deficit. Taxes are not endogenous to close the government's accounts as in the Bank's closure. With government spending on services fixed and negative public savings decreasing in magnitude – subsidies don't need to be financed any longer – government income increases with double digit growth rates in both regions. Using the same expression as before, the "money" freed up from subsidies is transferred to lower public debt instead of to consumers in the form of lower taxes. Thus, subsidy removal suppresses demand, and with falling demand imports as well as exports decrease. Consequently, unemployment rises and welfare decreases.

Figure 7 here

On the positive side, the foreign deficit is relatively stable and the public deficit is cut in half in SSA and almost eliminated in the developed world. Where would such an economy be headed? IMF adjustment programs often prescribe contractionary policies to induce trust and increase foreign capital inflow. In the best case, this might happen; in the worst case, unemployment and income losses spur political unrest and severely impede development.

[49] The welfare measure shown in this graph is the average of Compensating and Equivalent Variation, relative to base-year GDP. The former compares post- and pre-liberalization expenditure (given the level of utility) at post-liberalization prices; the latter does the same at base-year prices. The measures are standard, see Varian (1992) and the appendix. Equivalent Variation tends to be lower and is therefore the more conservative measure; the World Bank usually reports this one. The difference between the two is small, on average.

Radical tariff reform has opposite results. The current account and public deficits deteriorate, but employment, output, and welfare improve. The key to understanding these results is the same as in other closures and liberalization scenarios; it is the interaction between government revenue and deficit on the one side and the various demand responses (consumption, imports, and exports) on the other. Here, the government loses a source of revenue – tariffs – but still has to finance subsidies and other expenditures. With the deficit the adjusting variable, taxes do *not* increase and so do *not* crowd out consumption. Moreover, lower import prices increase demand for foreign product and lower costs for inputs – trade and domestic production expand. Value added rises with output, and employment, consumption and welfare follow.

However, if the willingness or ability to substitute imports for domestic product is moderate, the export response of an economically small region like SSA cannot be strong enough to counteract the import surge from ROW. Thus, the current account deficit increases.

Combined, liberalization of tariffs and subsidies brings about the worst of both, at least for the developing region: Foreign and public deficit rise, and consumption, output and employment fall. The benefits from lower import prices are too low relative to the contraction due to subsidy removal, but, on the other hand, the deficit lowering effects of the latter are not high enough to improve the public balances. As subsidies play a more important role in ROW, the deficit decreases. Still, global real output diminishes.

In a "likely" Doha outcome, we see the same principles at work as in the examples discussed so far. Our Doha scenario takes into account the state of the negotiations after Hong Kong. Firstly, developed country export subsidies will be phased out. Secondly, we reflect the major concerns of the negotiating blocks: developing countries demand "real"[50] decreases in domestic producer ("Amber") support in ROW while developed countries ask for improvements in non-agricultural market access in SSA. Therefore, our likely Doha outcome features a full removal of export subsidies and elimination of agricultural output subsidies in ROW and industrial

[50] Neither the U.S. nor the EU offers to lower agricultural "Amber" subsidies promise much more than domestic reforms and "box-shifting" would not have achieved in any case. See Oxfam press releases.

tariffs in SSA. The extent of this liberalization is certainly stylized, but it gives us a blueprint to discuss the interests of the involved parties. Figure 8 summarizes the simulation results for Bank and absorption closure in both regions. The lower part of the diagram shows changes in selected indicators for Sub-Saharan Africa, some of which are constant in the Bank's closure. The upper part shows changes in ROW's macro performance, leaving aside the current account, as that is simply the negative of SSA's. We observe the relatively high volatility in the "Keynesian" simulations, with risks especially for Africa, but as well slight employment losses in the developed world.[51]

Let's begin our analysis again with the Bank's closure, where deficits and employment are fixed. Lowering the agricultural subsidy reduces fiscal outlays, which get transferred to consumers through lower taxes. Hence, ROW's consumers experience an income increase and welfare gains. In SSA, the lower tariff rate decreases import prices for manufactures, what boosts imports in that sector and thereby increases total supply. The export response is tame, because ROW did not further improve its non-agricultural market access, so that domestic output decreases in the industrial sector. However, the fall in output in the agricultural sector abroad leads to an increase in export demand for agricultural product. The drop in tariff revenue, moreover, is not steep enough to strangle consumption completely – despite a fall in nominal consumption spending, welfare rises.[52]

As seen before, simulations under the absorption assumptions have opposite results: tariff removal is beneficial, as the increase in the deficit allows consumers to go on a spending spree, whereas subsidy removal has negative effects on output, employment and welfare because of the contractionary policy of the government. Consequently, our likely Doha scenario produces moderate welfare gains in SSA and small losses in the developed world.[53]

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[51] The results presented in Figure 8 are based on "normal" elasticity values.

[52] This clarifies the idea of the welfare measure: Despite nominal decreases in consumption, welfare increases. Why? The welfare measure compares expenditure pre- and post-liberalization as a function of "real" utility out of consumption and prices – if the rise in the former outweighs the latter, welfare can increase despite a trough in nominal spending.

[53] Kraev (2005) presents an analysis of the effects of trade liberalization on GDP. Even though the model details differ, the methodology as well as its aim are comparable: Endogenizing output, employment and current account in a CGE-framework allows to estimate future risks or past losses due to trade liberalization. The results presented in Kraev (2005) and here are not easily

It is important to realize how very sensitive all these simulation results are not only to the specific liberalization scenario and the base-year data set, but moreover to the assumptions made about which economic agents change their behavior and in what regard post-reform.

Unsurprisingly, the Bank's closure shows results where macroeconomic performance is overall more stable. Unsurprising, because most indicators policy makers pay attention to are held constant. Still, welfare depends on the specific simulation scenarios, and it is in fact rather straightforward to see negative welfare changes due to a consumption crowding-out.

Equally unsurprisingly, the Keynesian closure shows relatively volatile macro-behavior. Employment, output, current account, and public deficit changes have strong spillover effects onto economic activity. The multiplier effect from a higher government deficit and income gains from import adjustments have positive welfare effects, but, as discussed above, they pose great risks for an increasingly vulnerable economy. Figure 7 shows the high volatility in selected key indicators of Sub-Saharan Africa.

Lastly, we should note how crucial the size of the Armington trade elasticities is for all these effects. The simulations discussed thus far were all based on "normal" elasticities, meaning they average around 1.5, which represents a reasonable mid-point of a range supported by empirical research. It is obvious that a policy conclusion to the effect that "SSA should not liberalize because simulations show a negative welfare change of a third of a percentage point" is meaningless – or suggestive at best – because such a small change could be bigger in magnitude and/or have a different sign depending on the complex interaction of all parameters, base-year data, and functional and closure related assumptions. However, Figure 6 clearly shows the positive relationship in such a model between the magnitude of Armington elasticities and welfare effects in the small, dependent region.

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comparable. Government savings and foreign exchange inflows are fixed throughout scenarios, and either current account or employment (output) vary – which does not match either of our closure regimes. However, Kraev's research is consistent with the analyis presented here in the sense that as soon as one endogenizes current account and employment, trade liberalization induces macroeconomic volatility – mostly negative for developing regions.

Part IV: Conclusions

We finish with two sets of conclusions, one with regard to our critique of CGE (and especially World Bank) modeling of trade liberalization and the other about current WTO liberalization negotiations.

First, the Armington trade specification at the heart of Bank models is rife with problems. Its fundamental weakness is the "fiscal adjustment effect" described in detail in Part II. Instead of having a neutral impact on aggregate demand, a tariff reduction and the offsetting direct tax increase built into the LINKAGE specification lead to demand contraction. The *direct* impact of the higher tax on reducing real consumer spending is greater than the *indirect* effect of tariff reduction on cutting its cost because there are non-import cost components in the Armington aggregate supply price and the price applies to more components of demand than just consumption. The effects of subsidy removal go in the opposite direction. With roughly 5000 separate commodity markets in a full LINKAGE simulation and associated tariffs and subsidies interacting in extremely complicated fashion, the implication is that World Bank's estimates of its preferred indicators of "welfare gains" from liberalization are subject to biases of unknown and potentially large magnitude and direction. Beyond that, Armington overemphasizes potential benefits of liberalization by granting national economies monopoly power, and this sort of product differentiation is an inappropriate description of trade at the commodity level (which often takes the form of intra-firm trade by multinational corporations). In sum, although the Armington specification is convenient for modeling purposes, its empirical and theoretical defects render it almost useless in practical terms.

Second, the magnitude of the trade elasticities chosen for a model greatly affects its simulation results. The higher the elasticities, the stronger the substitution effect between imports and domestic products, leading to enhanced welfare gains and reduction of adverse shifts in the terms of trade. In the relevant World Bank publications, elasticities are usually set at levels higher than those supported by econometric evidence.

Third, LINKAGE muddles microeconomics and trade theory on the one hand with open economy macroeconomics on the other. Consistent with the former, the Bank model goes a long way toward describing a “general equilibrium” with 5000 markets. Inconsistent with the latter, LINKAGE hides national exchange rates – the key macro level prices – behind 5000 varying commodity prices and hundreds of factor prices. This level of disaggregation and detail adds little to clarification of the issues under debate and a lot to confusion about what the model is actually doing. Confusion is not alleviated by the Bank’s extremely complicated, Gothic model architecture.

Fourth, the choice of causality assumptions built into LINKAGE (“closure” in the jargon) is of critical relevance to simulation results. It is outright negligent to assume that the most central macroeconomic indicators do not change in response to any liberalization scenario. Especially in developing countries – with historically large trade deficits, huge debt problems, and a large informal economy with underemployment in modern sectors – fixing the current account, the government deficit, and employment makes no sense. One needs neither an economics degree nor modeling capacity to see that risks from trade liberalization appear diminished if the candidate “risky” variables are held constant. An honest simulation strategy should include various closure regimes, so that policy makers can assess different situations. As it is unlikely that there will be a consensus about the direction of causalities in the global economy any time soon, policy makers should be able to base their decisions – given their mandate – on a set of possible scenarios instead of the “World Bank version.” This is especially true in developing countries, where technical capacities and modeling expertise are often limited so that governments must depend on Bank advice.

Finally, even if they were estimated correctly by LINKAGE, its “little triangle” measures of welfare gains presuppose that the economy is always at full employment and that economic agents worldwide are basically uniform in tastes, access to resources, and income levels. Such a state of “Utopian capitalism” simply does not exist. Nor is it clear, under really existing capitalism, that international trade negotiators really know what the measures try to indicate. In practical

policy-making they are far more likely to pay attention to the macroeconomic indicators that World Bank models suppress.

What insight does the Bank model add to the controversy around the Doha Development Agenda? Due to the sheer size of LINKAGE and similar models, we may be able to learn about distributive issues: Which of the many sectors in which of the many countries win, which ones lose? Insisting on what we called above the *Bank's closure*, however, limits the relevance of LINKAGE's simulation results, because policy recommendations require a preamble spelling out the model's unrealistic assumptions about the current account, the government deficit, and employment of labor and capital.

Our model, although it incorporates a great deal of LINKAGE's unrealism, shows that

- if trade elasticities are lower than the Bank stipulates, Sub-Saharan African faces welfare losses even in an otherwise most optimistic situation which rules out all macroeconomic shocks;
- if the current account is allowed to respond to trade liberalization, and imports to one region grow stronger than that region's exports, it is Africa – and not the developed world – that faces a deteriorating trade balance;
- if the analysis includes the government deficit, the African public balance often deteriorates, whereas the rest of the world's fiscal position improves;
- if employment and income are variable, they might very well increase in Sub-Saharan Africa, but do so in tandem with mounting trade deficits and foreign debt, which renders these advances temporary.

Our final conclusion has to be that developing countries would be ill-advised to follow the radical recommendations of the World Bank's liberalization strategy insofar as it rests on results from the LINKAGE model.

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1 Appendix: The Model in Algebra

1.1 Value Added

1.1.1 Price Level

$$w\sum_{i=1}^{3} L_i + r\sum_{i=1}^{3} K_i = \sum_{i=1}^{3} Q_i V_i \tag{1}$$

$$\sum_{i=1}^{3} Q_i V_i = \sum_{i=1}^{3} \left(\alpha_i^{\theta_i} w^{1-\theta_i} + \beta_i^{\theta_i} r^{1-\theta_i}\right)^{\frac{1}{1-\theta_i}} V_i \tag{2}$$

1.1.2 Distribution

$$\frac{wL_i}{(QV)_i} = \Omega_i = \left(\frac{\delta Q_i}{\delta w}\right)\frac{w}{Q_i} = \alpha_i^{\theta} Q_i^{\theta-1} w^{1-\theta} \tag{3}$$

$$\frac{rK_i}{(QV)_i} = \Pi_i = \left(\frac{\delta Q_i}{\delta r}\right)\frac{r}{Q_i} = \beta_i^{\theta} Q_i^{\theta-1} r^{1-\theta} \tag{4}$$

1.1.3 Factor Demand

Shephard's Lemma gives factor-value added ratios as

$$\frac{K_i}{V_i} = \left(\frac{\beta_i Q_i[w,r]}{r}\right)^{\theta_i} \tag{5}$$

$$\frac{L_i}{V_i} = \left(\frac{\alpha_i Q_i[w,r]}{w}\right)^{\theta_i} \tag{6}$$

Given the factor prices, these equations provide employment levels. Under the assumption of full-employment, exogenous total employment L^* would be constrained in

$$\sum_i L_i = L^* \tag{7}$$

Under the full employment assumption, Shephard's Lemma determines the factor prices:

$$r = \left(\frac{K_i}{V_i}\right)^{-\frac{1}{\theta_i}} \beta_i Q_i[w,r]$$

$$w = \left(\frac{L_i}{V_i}\right)^{-\frac{1}{\theta_i}} \alpha_i Q_i[w,r]$$

so that the wage changes positively with V and Q.

1.2 Armington Prices

The domestic Armington prices are a CES-aggregate of the domestic price P, the market price of intraregional imports Z^{in} and the market price of imports from abroad, Z'.

$$Z_i = (a_i^{\sigma_i} P_i^{1-\sigma_i} + b_i^{\sigma_i} Z_i^{in1-\sigma_i} + c_i^{\sigma_i} Z_i'^{1-\sigma_i})^{\frac{1}{1-\sigma_i}} \text{ where} \tag{8}$$

$$Z_i' = \psi'^{xt} \tau_i^{xt} e Z_{fi} \text{ and } Z_i^{in} = \psi^{in} \tau_i^{in} Z_i \tag{9}$$

$\psi'^{xt} = (1 - z_E'^{xt})$ and $\psi^{in} = (1 - z_E^{in})$ are the price-reducing export subsidy factors on external and internal imports. Note that the market price of imports from abroad, Z', is increased by the domestic tariff rate on external imports τ^{xt} and decreased by the *foreign* subsidy rate $z_E'^{xt}$.

1.3 Domestic Price

$$P_i X_i = \sum_{j=1}^{3} h_{ji} Z_j X_i + \sum_{j=1}^{2} h'_{ji} \tau_j^{xt} \psi_j'^{xt} e Z_{fj} X_i - s_i X_i + Q_i V_i \tag{10}$$

$$P_i = \sum_{j=1}^{3} h_{ji} Z_j + \sum_{j=1}^{2} h'_{ji} \tau_j^{xt} \psi_j'^{xt} e Z_{fj} - s_i + Q_i \frac{V_i}{X_i} \tag{11}$$

$$\Rightarrow \mathbf{P}[\mathbf{Z}, \mathbf{w}, \mathbf{r}, \mathbf{e}] \tag{12}$$

We can write the linear unit cost function (the dual to the Leontief technology) as

$$P_i = f_i + (1 - f_i) Q_i \text{ where} \tag{13}$$

$$f_i \equiv \sum_{j=1}^{3} h_{ji} Z_j + \sum_{j=1}^{2} h'_{ji} \tau_j^{xt} \psi_j'^{xt} e Z_{fj} - s_i \tag{14}$$

f_i depends on input-output coefficients, tariff- and subsidy rates and varies with the latter two. The derivative of the cost function with respect to Q provides the usage ratio

$$\frac{\Delta P_i}{\Delta Q_i} \equiv \frac{V_i}{X_i} = 1 - f_i \tag{15}$$

1.4 Demand Functions: Domestic Product and Trade

Imports (and domestic product) are a function of composite supply and *final*, meaning tariff- and subsidy-ridden, prices. Shephard's Lemma provides the "real" levels of demand for domestic product and imports,

given their relative prices.

$$X_i = \left(\frac{a_i Z_i}{P_i}\right)^{\sigma_i} A_i \tag{16}$$

$$M_i^{in} = \left(\frac{b_i Z_i}{Z_i^{in}}\right)^{\sigma_i} A_i \tag{17}$$

$$M_i^{xt} = \left(\frac{c_i Z_i}{Z_i'}\right)^{\sigma_i} A_i \tag{18}$$

Final nominal (Armington) imports of sector i goods, intermediate (Leontief) imports and total nominal imports are, in turn

$$M_{i,fin} = \left\{\tau_i^{in} Z_i \left(\frac{b_i Z_i}{Z_i^{in}}\right)^{\sigma_i} + \tau_i^{xt} e Z_{fi} \left(\frac{c_i Z_i}{Z_i'}\right)^{\sigma_i}\right\} A_i \tag{19}$$

$$M_{i,int} = \sum_{j=1}^{3} h_{ij}' \tau_i^{xt} e Z_{fi} X_j \tag{20}$$

$$M_i = \left\{\tau_i^{in} Z_i \left(\frac{b_i Z_i}{Z_i^{in}}\right)^{\sigma_i} + \tau_i^{xt} e Z_{fi} \left(\frac{c_i Z_i}{Z_i'}\right)^{\sigma_i} + \sum_{j=1}^{3} h_{ij}' \tau_i^{xt} e Z_{fi} \left(\frac{a_i Z_i}{P_i}\right)^{\sigma_i}\right\} A_i \tag{21}$$

1.5 Armington Material Balance

Total Armington composite supply is the sum of output across sectors:

$$\sum_{i=1}^{3} Z_i A_i = \sum_{i=1}^{3} P_i X_i + M_{i,fin} \tag{22}$$

$$\sum_{i=1}^{3} Z_i A_i = \sum_{i=1}^{3} \left[\sum_{j=1}^{3} h_{ij} Z_i X_j + Z_i C_i + Z_i G_i + Z_i Inv_i + Z_i Ex_i\right] \tag{23}$$

$$\sum_{i=1}^{3} P_i X_i = \sum_{i=1}^{3} \left[\sum_{j=1}^{3} h_{ji} Z_j X_i + \sum_{j=1}^{2} h_{ji}' \tau_j^{xt} e Z_{fj} X_i - s_i X_i + Q_i V_i\right] \tag{24}$$

where

- $Z_i C_i$ is the value of consumption of sector i Armington composite product,
- G_i – real government spending – is exogenous and equal to zero in the agricultural and industrial sector,
- Inv_i – real investment – is exogenous. $Inv_i = 0$ in the agricultural sector & services.

Using $X_i = \left(\frac{a_i Z_i}{P_i}\right)^{\sigma_i} A_i$ in the sectoral Armington material balance, we get the following expressions for real and nominal balances

$$Z_i A_i = \sum_{j=1}^{3} h_{ij} Z_i \left(\frac{a_i Z_i}{P_i}\right)^{\sigma_i} A_i + C_i + G_i + Inv_i + Z_i Ex_i \tag{25}$$

$$A_i = \sum_{j=1}^{3} h_{ij} \left(\frac{a_i Z_i}{P_i}\right)^{\sigma_i} A_i + C_i + G_i + Inv_i + Ex_i \tag{26}$$

Setting $D_{i,fin} = C_i + G_i + Inv_i + Ex_i$, letting a prime denote a column vector, bold face a matrix and a tilde a matrix with elements on the main diagonal the Leontief system is

$$A' = \mathbf{H}.\widetilde{\boldsymbol{\chi}} A' + D'_{fin} \tag{27}$$

$$A' = \left[\mathbf{I} - \mathbf{H}.\widetilde{\boldsymbol{\chi}}\right]^{-1} D'_{fin} \tag{28}$$

1.6 Macroeconomic Balance

$$\left[Z_2 Inv_2 - s[w,r] \sum_{i=1}^{3} \gamma_i X_i\right] + [Z_3 G_3 - Y_G] + \left[\sum_{i=1}^{2} Z_i Ex_i - \sum_{i=1}^{2} e Z_i M_i\right] = 0 \tag{29}$$

1.7 Savings

The function for the sectoral savings rate $s[w,r]$ is

$$s_r \sum_i \Pi_i + s_w \sum_i \Omega_i \Leftrightarrow s_r \sum_i (1 - \Omega_i) + s_r \sum_i \Omega_i \Leftrightarrow s_r - (s_r - s_w) \sum_i \Omega_i \tag{30}$$

$$s[w,r] = s_r - (s_r - s_w) \sum_i \alpha_i^{\theta} Q_i^{\theta-1} w^{1-\theta} \tag{31}$$

$$\frac{\Delta s[w,r]}{\Delta w} < 0 \text{ with } \theta < 1 \tag{32}$$

The level of savings for a given level of income then is

$$Sav = s[w,r] \sum_{i=1}^{3} Q_i V_i = s[w,r] \left(w \sum_{i=1}^{3} L_i + r \sum_{i=1}^{3} K_i\right) \tag{33}$$

1.8 Consumption: Linear Expenditure System

Representative (indirect) utility maximization

$$\max \sum_i u_i[C_i] = \sum_i m_i Log(C_i - \xi_i) \text{ subject to } \sum_i Z_i C_i = D \tag{34}$$

with $\sum_i Z_i \xi_i = F$ and $\sum_i m_i = 1$.

Derivation of the consumption function:

1. Frisch parameter: $\lambda = \frac{1}{D-F} \Longrightarrow \frac{\vartheta\lambda}{\vartheta D}\frac{D}{\lambda} = -\frac{D}{D-F} = \beta \sim -2$

2. Engel elasticity: $\eta_i = \frac{\vartheta C_i}{\vartheta D}\frac{D}{C_i} = \frac{m_i D}{P_i C_i} = \frac{m_i}{\phi_i} \Rightarrow$ Engel aggregation $\sum_i m_i = \sum_i \eta_i \phi_i = 1$

3. Floor: $m_i(D-F)\frac{1}{P_i} + \xi_i = \frac{m_i D}{Z_i \eta_i} \Longrightarrow \xi_i = \frac{D}{Z_i}(\phi_i - m_i \sigma^D)$ with $\sigma^D = -\frac{1}{\beta}$

4. Let $\mu_i = (\phi_i - m_i\sigma^D) = \phi_i(1 - \eta_i\sigma^D)$

$$C_i = (D-F)\frac{\eta_i\phi_i}{Z_i} + \xi_i \tag{35}$$

$$\sum_{i=1}^{3} \xi_i Z_i = F = D\sum_{i=1}^{3}\mu_i \tag{36}$$

$$C_i = D\left(1 - \sum_{i=1}^{3}\mu_i\right)\frac{\eta_i\phi_i}{Z_i} + \frac{D}{Z_i}\mu_i \tag{37}$$

$$= \frac{D}{Z_i}\left[\left(1 - \sum_{i=1}^{3}\mu_i\right)\eta_i\phi_i + \mu_i\right] \tag{38}$$

Total, nominal disposable income is the sum of sectoral value added less nominal savings and nominal (lump-sum) taxes.

$$D = (1 - s[w,r])\sum_{i=1}^{3} Q_i V_i - Tax = (1 - s[w,r])\left(w\sum_{i=1}^{3} L_i + r\sum_{i=1}^{3} K_i\right) - Tax \tag{39}$$

1.9 Welfare Function(s)

The representative utility maximization exercise in the Linear Expenditure System can be summarized as

$$u^* \equiv \sum_i u_i[Z_i, D] = \max u[C_i] \text{ subject to} \sum_i Z_i C_i = D^* \tag{40}$$

The dual problem to utility maximization is expenditure minimization:

$$D^* \equiv \sum_i e_i[Z_i, u_i] = \min \sum_i Z_i C_i \text{ subject to } \sum_i u_i[C_i] = u^* \tag{41}$$

The relation between the indirect utility function and the expenditure function is

$$e_i[Z_i, u^*] \equiv D^* \tag{42}$$

what means that the minimum expenditure at prices Z_i necessary to achieve the utility level u^* is income D^*.

1.9.1 Compensating Variation

$$\Delta D^{CV} = e[Z_i^{\mathbf{pl}}, u^{*,\mathbf{pl}}] - e[Z_i^{\mathbf{pl}}, u^{*,\mathbf{by}}] \tag{43}$$

1.9.2 Equivalent Variation

$$\Delta D^{EV} = e[Z_i^{\mathbf{by}}, u^{*,\mathbf{pl}}] - e[Z_i^{\mathbf{by}}, u^{*,\mathbf{by}}] \tag{44}$$

1.9.3 Functional Form

The original utility function and the consumption function from the optimization procedure are

$$\begin{aligned}
\sum_i u_i[C_i] &= \sum_i m_i Log(C_i - \xi_i) \equiv u & (45)\\
C_i &= \frac{D}{Z_i}\left[\left(1 - \sum \mu_i\right)\eta_i\phi_i + \mu_i\right] \text{ and} & (46)\\
\xi_i &= \frac{D}{Z_i}\mu_i & (47)
\end{aligned}$$

so that the level of utility as a function of prices and income is

$$u^* = \sum_i m_i Log\left[\frac{D}{Z_i}\left(1 - \sum \mu_i\right)\eta_i\phi_i\right] \tag{48}$$

The inverse of the (indirect) utility function gives the expenditure function

$$\begin{aligned}
\exp^u &= \exp^{\sum_i m_i Log\left[\frac{D}{Z_i}(1-\sum \mu_i)\eta_i\phi_i\right]} & (49)\\
\exp^u &= \left[D\left(1 - \sum \mu_i\right)\right]^{\sum m_i} \prod\left(\frac{m_i}{Z_i}\right)^{m_i} & (50)\\
e[Z_i, u] &= \left[\exp^u \prod\left(\frac{m_i}{Z_i}\right)^{-m_i}\right]^{\frac{1}{\sum m_i}} \left(1 - \sum \mu_i\right)^{-1} \equiv D & (51)
\end{aligned}$$

Evaluating the expenditure function at different utility levels and either base-year or post-liberalization prices gives the Equivalent and Compensating Variation, respectively.

1.10 Closure Rules

1.10.1 Elasticities: The Bank's Closure

- Exogenous: Government deficit, current account, (full) employment levels, current account
- Endogenous: Taxes, factor prices, exchange rate, investment

- **Public balance**: First, recall the government's balances. Exogenous variables are indicated by a bar. Budget constraint (with a fixed deficit), income and flows of funds are, respectively

$$\begin{aligned} Z_3\overline{G_3} + \overline{Sav_G} &= Y_G^{Exp} && (52)\\ Sub + Tax + Sub_{Exp} + Tar &= Y_G \Leftrightarrow Tax = Y_G - Sub - Sub_{Exp} - Tar && (53)\\ \overline{Sav_G} + B - \overline{CA} &= 0 && (54)\\ Y_G^{Exp} &= Y_G && (55) \end{aligned}$$

  The level of borrowing from the private sector B balances the flows of funds. The budget constraint – and therewith income – is fully determined from a given level of (negative) public savings and the exogenous level of real government spending, G_3. The value of Y_G still depends on Z_3, but nevertheless Y_G follows. With fixed subsidy- and tariff-rates, taxes adjust residually to match Y_G.

  The government's accounts can be summarized as the difference between government expenditure, bonds and income, which has to equal the negative of the foreign deficit:

$$B - Sav_G = -\overline{CA} \quad (56)$$

- **Private balance**: With investment savings-driven, B determined in the government's flows of funds and savings a function of factor prices and value added, nominal investment is the difference between private savings and bonds, and real investment is

$$Z_2 Inv_2 + B - Sav = 0 \Rightarrow Inv_2 = \frac{Sav - B}{Z_2} \quad (57)$$

- **Foreign balance** The current account is fixed at the base-year level. e adjusts to revalue the trade flows such that this condition is satisfied.

- **Full employment constraint:** The full – or fixed – employment assumption, first, allows to endogenize factor prices and secondly, implies that shocks to the exogenous variables affect sectoral employment levels, but not the overall level of employment. Thus,

$$\begin{aligned} \overline{L} &= L_{Agr} + L_{Ind} + L_{Ser} && (58)\\ \overline{K} &= K_{Agr} + K_{Ind} + K_{Ser} && (59) \end{aligned}$$

1.10.2 Absorption: A Keynesian Closure

Exogenous: Real investment, government spending on services, factor prices, exchange rate

Endogenous: Employment level (unconstrained), current account, government deficit

- **Private balance**: Savings are a function of wages and value added. With investment exogenous, B adjusts the private flows of funds:

$$Z_2\overline{Inv_2} + B - Sav[w, QV] = 0 \Rightarrow B = Sav[w, QV] - Z_2\overline{Inv_2} \tag{60}$$

- **Public balance**: Revenue (Sub, Tax, Sub_{Exp}, Tar – in parts negative) determines government income, and the government adjusts its deficit in order to finance all expenditures. Thus, Sav_G is set in the first equation below. With B following from the private flows of funds, it has to be the current account that adjusts the government's flows of funds.

$$\begin{aligned} Z_3\overline{G_3} + Sav_G &= Y_G^{Exp} && (61)\\ Sub + Tax + Sub_{Exp} + Tar &= Y_G && (62)\\ Sav_G + B - CA &= 0 && (63) \end{aligned}$$

  The balances are

$$B - Sav_G = -CA \tag{64}$$

- **Foreign balance**: The CA adjusts to the fixed exchange rate.

- **Factor markets**: In this closure, employment is endogenous.

Figures

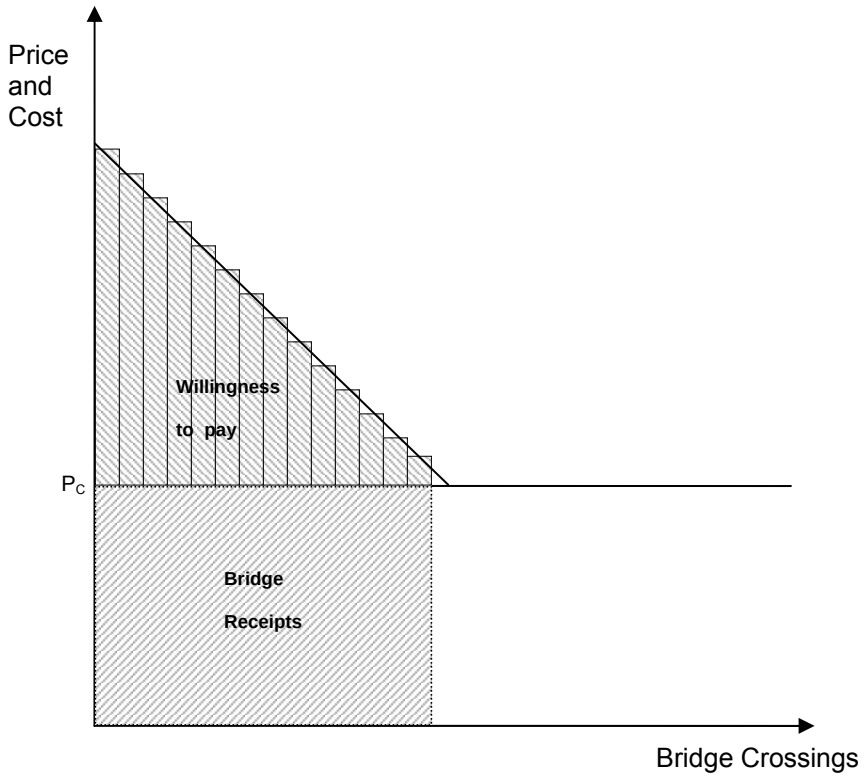

Figure 1: The original idea of consumer surplus

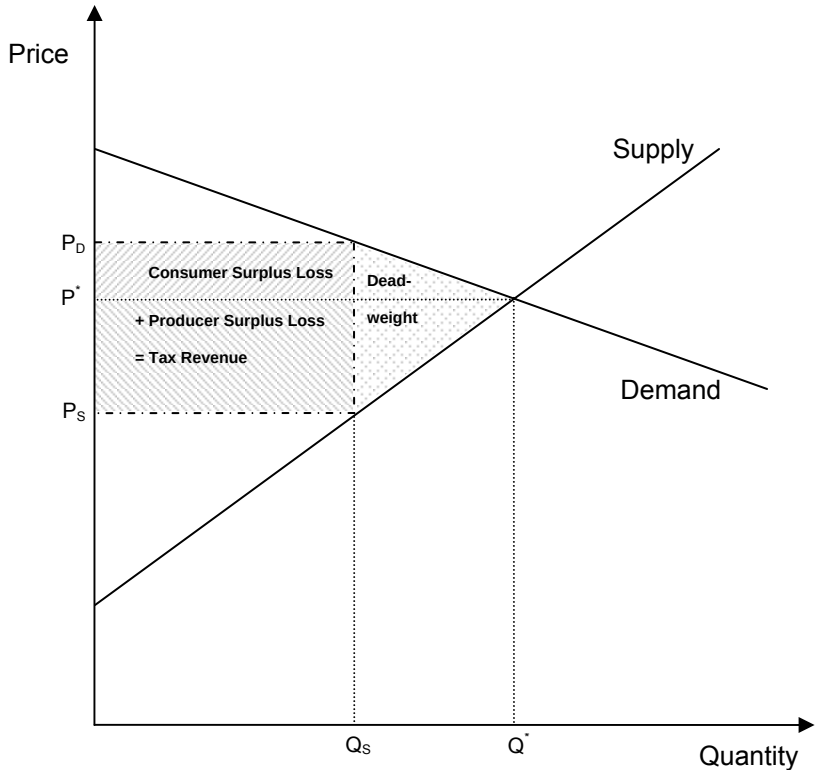

Figure 2: “Little Triangles” show the calculation of the deadweight loss after the imposition of a tariff

	Bank's Closure	Absorption Closure
Public Balance	Taxes adjust to a fixed government deficit.	The government deficit adjusts to finance expenditures.
Private Balance	Investment adjusts to Savings.	Investment is exogenous.
Foreign Balance	The exchange rate adjusts to hold the current account constant.	The current account adjusts according to demand shifts, and the exchange rate is exogenous.

Figure 4: An overview of the different closure rules.

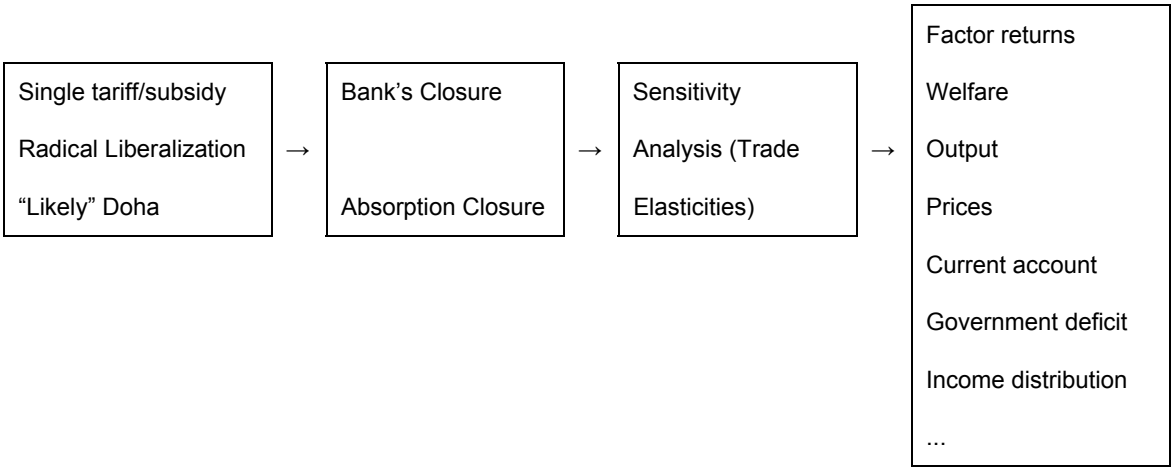

Figure 5: A simple presentation of our simulation strategy

Figure 6

Welfare Gains: Full Liberalization in the Bank's Closure
with different Armington Elasticities

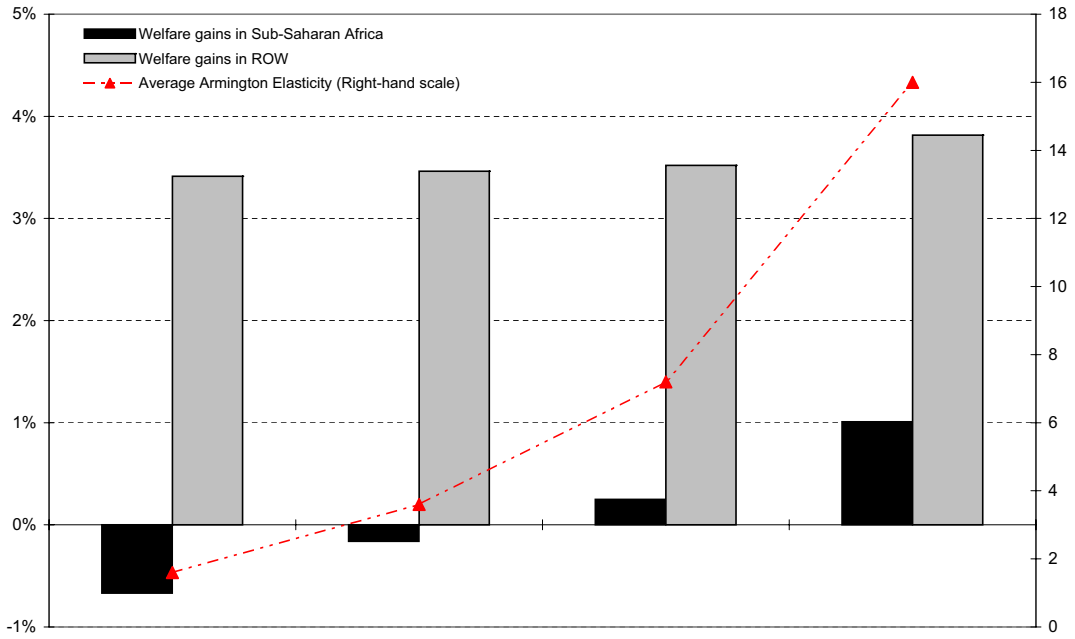

Figure 7

Selected Indicators for Sub-Saharan Macro Performance: Absorption Closure

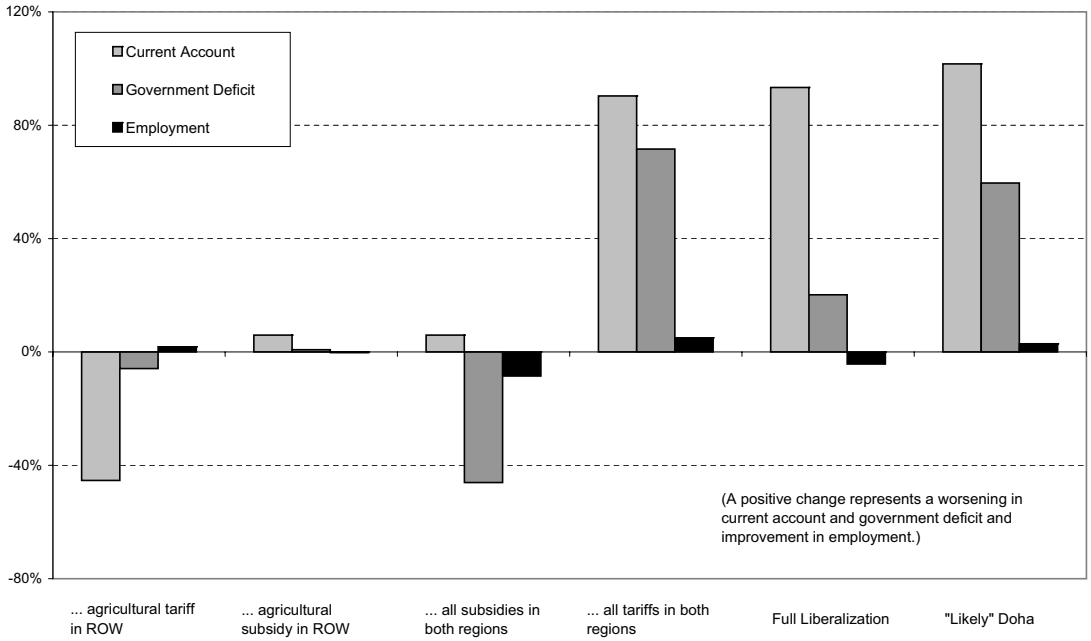

Figure 8

"Likely" Doha Outcome under different Closures

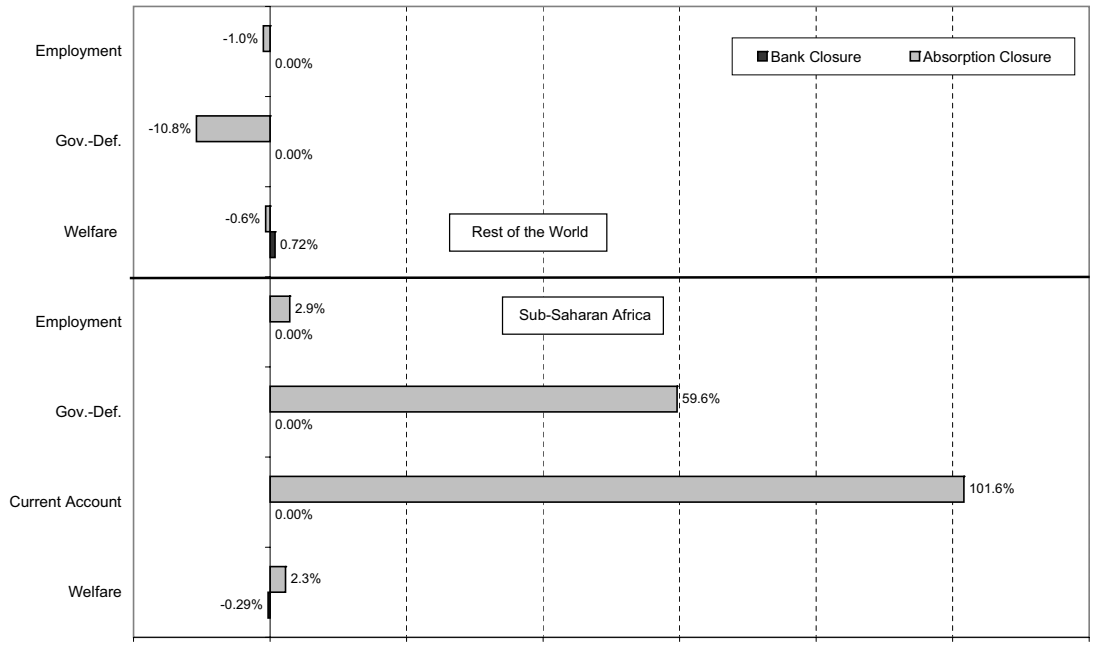

Figure 3

Two country SAM: Sub-Saharan Africa and "Rest of the World"

1997 Billion U.S. Dollars. Source: GTAP Database 5.0, except Tariff data

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	21	22	23	24	25	26	27	28	29	20	
	SSA	Cost:A	Cost:I	Priv	Gov	Exp	Inv	M	Treas	Aid	SUM									SUM	Cost:A	Cost:I	Priv	Gov	Exp	Inv	M	Treas	Aid	ROW	
A	M:A			6.64				-6.64															0.00				0.00			M:A	A
B	Armington:A	35.82	7.30	78.84		14.31		-6.64			129.63			Bilateral Trade Matrix						4,728.21	1,419.53	516.45	2,585.27		538.62		-331.65			Armington:A	B
C	M:I			22.06			18.05	-40.10						Intra-	Extra-	Extra-	Intra-						1,565.21			1,180.77	-2,745.97			M:I	C
D	Armington:I	29.00	197.84	152.55	53.82	65.17	59.24	-40.10			517.51			Regional	Regional	Regional	Regional			48,771.86	1,070.46	18,852.93	15,196.00	4,291.94	5,645.27	6,461.23	-2,745.97			Armington:I	D
E	Factor-Income	60.55	278.99								339.54			SSA	SSA	ROW	ROW			29,482.54	2,042.70	27,439.85								Factor-Income	E
F	Gov-Income	-2.77	-6.62	41.34							42.20	10.25	Tariff Revenue					Tariff Revenue	366.31	3,545.36	-117.50	-1,192.88	4,489.42								Gov-Income	F
G	FoF:Priv			66.81			-59.24		-7.58		0.00			World	World	World	World			0.00			7,211.85			-6,461.23		-750.62		FoF:Priv	G
H	FoF:Gov				-11.63				7.58	4.05	0.00	Incl Tariff	Incl Tariff	Prices	Prices	Prices	Prices	Incl Tariff	Incl Tariff	-0.02				-746.58				750.62	-4.05	FoF:Gov	H
I	Imp(H,Agr)	2.41	0.71					6.64			9.76	0.71	9.05	0.61	7.77	-7.77	-530.84			-538.62					-538.62					Exp(F,Agr)	I
J	Imp(H,Ind)	4.62	39.29					40.10			84.02	8.24	75.78	7.49	67.66	-67.66	-5,577.61			-5,645.27					-5,645.27					Exp(F,Ind)	J
K	Exp(H,Agr)					-14.31					-14.31			-0.61	-13.70	13.70	530.84	15.62	615.78	631.40	206.88	92.87				331.65			Imp(F,Agr)	K
L	Exp(H,Ind)					-65.17					-65.17			-7.49	-57.67	57.67	5,577.61	58.25	5,856.49	5,914.74	106.13	3,062.64				2,745.97			Imp(F,Ind)	L
M	Aid									-4.05	-4.05			0.00	4.05	-4.05	0.00			4.05								4.05		Aid	M
N	SUM	129.63	517.51	339.55	42.19	0.00	0.00	0.00	0.00	0.00											4,728.20	48,771.85	29,482.54	3,545.36	0.00	0.00	0.00	0.00	0.00	SUM	N

Macro-Balance SSA:

Private			Government			International		
Investment	Lending	Saving	G-exp.	Borrowing	G-Income	Export	Imports	
59.24	7.58	66.81	53.82	-7.58	42.20	79.47	83.53	-0.01

Ratio to Value Added: 339.54

S		I	G		Y-G	E	M	CA/GDP	Def/GDP
0.17		0.20	0.16		0.12	0.23	0.25	-0.01	0.03

Macro-Balance ROW:

Private			Government			International		
Investment	Lending	Saving	G-exp.	Borrowing	G-Income	Export	Imports	
6,461.23	750.62	7,211.85	4,291.94	-750.62	3,545.36	6,183.88	6,179.83	0.02

Ratio to Value Added: 29,482.54

S		I	G		Y-G	E	M	CA/GDP
0.22		0.24	0.15		0.12	0.21	0.21	0.00