A VIRTUAL DYNAMIC APPLIED GENERAL EQUILIBRIUM MODEL OF AFRICA: SPECIFICATIONS AND SIMULATIONS

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ABSTRACT

African economic performance has been markedly worse than that of other regions. Thus, the governments of African countries have assumed major responsibilities for economic reforms and growth. Along with these responsibilities has come an increased awareness of the interrelatedness of different sectors of a national economy and of the need for co-ordination of policies that had previously been debated in terms of their direct impacts on individual sectors. Therefore, this project proposes a multi-regional dynamic applied general equilibrium framework within which to study a very wide range of economic problems that have always been presented in isolation from one another. As a research output,
a prototype virtual economy model of Africa will be demonstrated.

1.0 PROBLEM STATEMENT

For the past four decades, the economic and non-economic problems facing African has been very serious. As at today Africa remains the poorest region and her economic performance has been markedly worse than that of other regions. Thus, the governments of African countries have assumed major responsibilities for economic reforms and growth. Along with these responsibilities has come an increased awareness of the interrelatedness of different sectors of a national economy and of the need for coordination of policies
that had previously been debated in terms of their direct impacts on individual sectors. In attempting to describe their economies, economists in many countries have applied certain models that are by now widely known. The need for certain kinds of frameworks or models is now so widely recognized that in many cases government agencies have assumed responsibility for maintaining national income and products accounts, input output models and models for development planning.

Thus, the walrasian general equilibrium model provides an ideal framework for appraising the effects of policy changes on resource allocation and for assessing who gains and loses, policy impacts that are not well covered by empirical macro econometric models. Most contemporary applied general equilibrium models are numerical analogs of traditional two-sector general equilibrium models and earlier analytic work with these models has examined the distortion effects of taxes, tariffs and other policies (see Nwaobi, 1997). However, there are many examples of both partial and general equilibrium multi-region models. the transportation problem, formulated by Kantororich in 1939 and Hitchcock in 1941 and solvable with linear programming (LP) algorithms, is the starting point for the partial-equilibrium literature. The classic problem is to minimize the transportation cost that arises when fixed demands in one set of regions (points in space) are satisfied by the transportation of a homogenous commodity from a second set o f regions, each of which has a fixed supply. The model solution generates quantities shipped (by regions of origin and destination) and regional prices. Both price and quantity variables may be zero, i.e., the model endogenously selects the "regimes" for markets (full utilization with a positive market clearing price or excess supply with a zero price) and transportation flows (links may be active, with a positive flow, or inactive, with a zero flow). The solution may be viewed as market equilibrium, albeit subject to the restrictive assumption of fixed, non-price-responsive, supply and demand quantities.

Enke (1951) and Samuelson (1952) extended the transportation model by introducing price-responsive regional demand and supply functions. Samuelson's formulation shows that the problem of maximizing “net social payoff” subject to regional commodity balance equations generates a set of optimality conditions that define equilibrium in each regional market. Much subsequent research was directed toward making Samuelson’s model operational. Takayama and Judge (1964) generalized Samuelson’s approach to multiple products and showed that, if written with linear demand and supply functions, the resulting model could be solved with available quadratic programming (QP) algorithms. Duloy and Norton (1973) linearized the demand side using grid techniques and substituted activity analysis with input substitutability for explicit supply functions; the resulting model could be solved with, at the time, more efficient LP algorithms. Both the QP and LP approaches require that the demand functions be symmetric, a condition that empirically estimated systems is unlikely to satisfy. This shortcoming was overcome with linear-complementarily programming (Takayama and Judge, 1971) and by imposing both price and quantity equilibrium conditions in the primal problem.

While these partial-equilibrium models have evolved considerably from the initial transportation model, they have maintained its basic trade treatment: the model endogenously selects the quantities traded, including the regime for each tradable commodity and regional link (which maybe inactive or may ship in one of the two directions), under the assumption that tradable commodities are homogenous or perfectly substitutable irrespective of source or destination. In the economy wide modeling tradition, Isard (951, 1990) developed the method for the basic multi-region, input-output model. As opposed to the optimization approach typical of partial-equilibrium models, his model was formulated as a set of simultaneous linear equations. The early multi-region, input-output models suffered from restrictive assumptions similar to those of national input-output models, including fixed production coefficients (excluding input substitutability), and the absence of supply constraints. For Isard's model, the strong assumption of fixed trade coefficients was added to the list. While traded quantities are endogenous (drive by production levels), the inter-regional and international trade regimes are imposed exogenously by the structure of trade coefficients in the base data set. Much of the subsequent multi-region, input – output literature has been geared toward introducing less restrictive assumptions while maintaining the attractive feature of capturing inter-sectoral and regional links throughout the economic system and extending the models to emerging issues such as the environment. In contrast, with the partial equilibrium modes, these models do no permit regime shifts in the trade structure.

The more recent CGE literature started out with single-region nation models. The earliest national multi-region model was done by the Australian ORANI project, which relied on a "top-down" approach (Dixon et al., 1982). Since the mid-1980s, a substantial number of “bottom-up” models have emerged, i.e., models where the primary driving force is derived from the decisions of micro agents. Most single-country models have been applied to the United States and Canada; there is also a growing literature on multi-country models in which countries represent regions. As opposed to the basic in – output model, CGE models tend to be characterized by price-endogeneity, price-responsive input substitution, and constrained factor supplies. However, available multi-region CGE models are very similar to multi-region input – output models in their treatment of inter-regional trade: space is rarely considered explicitly and most models assume product differentiation using the Armington approach, often complemented by a constant – elasticity of transformation formulations to capture quality differences between output supplied to different destinations.

In recent years, many countries have undergone changes in trade and exchange rate policies. Policy shifts in these areas may have very different effects across regions due to regional differences in economic structure and the existence of high transportation and communications costs. When, as a result, market links across regions are weak, the “national” economy may be better seen as a collection of imperfectly linked regional economies. In this environment, changes in national policy may have little effect on some regions when the changes in prices are large enough to cause regional producers and consumers to react to changes in prices external to the region – generating sectoral trade flows where before particular regional markets were autarkic. In the literature on CGE models, a growing number of regionally disaggregated models have emerged in recent years, not only for single countries but also multi-country models. However, these models have rarely explicitly treated geographical space or permitted "regime shifts" for trade flows: thus if for the base solution, one region exports to another region, then this trade flow will also be present in all other model simulations. Thus, linkages between global trade expansion and wages have been intensively debated since the Uruguay Round. However, there is apprehension in high – income countries about global (downward) convergence of wages, particularly among unskilled workers. These concerns have been intensified by financial globalization where capital has an unprecedented degree of mobility and is thought to ameliorate wage convergence.

The intuition behind the convergence concept (essentially stolper – Samuelson) with a twist of international capital movement is relatively appealing, making it easy to incorporate in a wide variety of anti-globalization agendas. And from another perspective, may domestic wage inequality in poor countries. The empirical basis of these controversies, however, has remained relatively weak, and this has hindered a deeper understanding and more reasoned debate about the processes at work. This project therefore makes a practical contribution to the issue with an empirical simulation framework to examine detailed trade, employment and wage patterns and their future evolution. In particular, we intend to develop and implement a virtual dynamic applied CGE model of African that can forecast the likely course of international employment and wage adjustments under different policy scenarios.

2.0 OBJECTIVES

A common criticism of empirical economics is that it pays insufficient attention to discriminating between competing explanations of the same phenomena. Yet, interaction and heterogeneity of agents are pervasive characteristics of economic processes. However, economic theory has neglected these features to a large extent. Instead, the paradigm of modeling representative agents has emerged, which by its very construction has eliminated any considerations of interaction and heterogeneity. The representative – agent's methodology originated from the need of developing micro-foundations of assumed macro-economic behavior, i.e., by tracing back the market behavior of firms or households to their underlying objectives of profit and utility maximization. Overtime, this seemed only possible with an extremely limited number of agents entering economic models. However, at the sometime, available results on the no-conservation of key properties of demand and supply functions under aggregation served as a warning against the limitations of this approach.

More recently, a number of developments have brought the neglected items of interaction and heterogeneity; imperfect competition, and inter-temporal dynamics to the fore again. Driven by new empirical insights, newly available theoretical tools and availability of modern technologies allowing stimulating large numbers of interacting agents, research in this way has become a demanding field.

Specifically, the objectives of this project are stated as follows:

(1) To formulate a multi-regional dynamic applied general equilibrium model of Africa.

(2) To disaggregate the African block so as to explicitly include sub-regional blocks and to better reflects the peculiarities of typical African economies.

(3) To simulate each of the regional blocks under some alternative plausible assumptions about the direction of economic policy in developed countries in order to make projection about the possible implications of these trends for the Africa's macroeconomic aggregates in the 21^{st} century.

(4) And finally, to provide a public access to the best available evaluation of empirical knowledge about macroeconomic

interactions among nations and the implications of that knowledge for national macroeconomic policies.

3.0 METHODOLOGY

The complication of an input – output table for the US economy by Leontief (1936, 1937) laid the groundwork for the development of multi-sector models. On the basis of this input-output accounting framework, Leontief's open static input – output model was constructed. Although the input – output models are consistency models and capable of capturing major elements of interdependence in an economy, they have a number of shortcomings. The development of linear programming (LP) models provided another class of multi-sector models in the early 1960s. The LP models managed to overcome some of the shortcomings and limitations of the early input – output models by providing a methodology to introduce primary factor constraints and offering the possibility of introducing prices explicitly into the analysis. In these models, an explicit objective functions is introduced which, has to be optimized subject to certain (linear) constraints.

The Evans (1972) model of the Australian economy and the Goreux (1977) model of the Ivory Coast can be regarded as excellent examples of extensions of LP models. Also LP models were treated as at Least approximations to CGE models (Dervis et al, 1982). However, the development of CGE modeling can be treated as a natural extension of input – output and LP models with the inclusion of an endogenous output and price system, neoclassical substitutability in production and demands, the optimization behavior of individual agents and a complete treatment of income flows in an economy. Srinivasan and whalley (1986) argued that the major feature of the numerical general equilibrium approach is its attempt to blend theory and policy so as to both improve the analytic foundations of policy evaluation work and to bring the theoretical work that already exists in the literature more fully into the policy debate.

While their popularity has surged over the last two decades to the point where they now dominate the policy – modeling scene, computable general equilibrium (CGE) models have also become the objects of some criticism. Typical these models assume optimizing behavior on the part of both consumers and producers when it comes to intra-temporal decisions, but inter-temporal decisions savings and investment) are treated in a rough and ready manner. For example, consumers are assumed to save a fixed share of income, and investment decisions are based on historical shares or current rates of return to capital. Savings and investment decisions are not "forward – looking". Yet, for the within – period decisions, these same consumers and producers solve fairly complicated optimizing problems and take into account the information contained in all the prices in the economy.

In our proposed frameworks, it is arguably the regional CGE model of open economies. Here, the model solves for the set of intra- and inter temporally consistent prices. Both savings and investment are the result of dynamic optimization based on future prices, which are, in turn, consistent with the realized levels of savings and investment. The dynamic component of the model operates by updating overtime all the exogenous variables entering the static model through a set of inter temporal linkages (using perfect – foresight dynamics).

The database for our proposed research study is the Global Trade Analysis Project (GTAP). This database supports quantitative economic analysis not only in conjunction with the GTAP model but also with any multi-region model. With the desegregation composed of at least of 65 regions and 57 sectors, along with better-quantified data inputs and the improved construction procedure, is now a much bigger and better database compared to the earlier versions. The database is produced through the joint effort of external data contributors, including some individuals from the consortium member agencies, and staff at the center for Global Trade Analysis (CGTA). Typically, the external data contributors proved domestic databases (input – output tables) and international data sets such as trade data and protection data while CGTA handle the database construction and Assembly. A new version of GTAP database is produced approximately every eighteen months. Under this cycle, six months are devoted to developing the requirements for the database construction and securing data from external contributors. Another six months are allocated for the preparation of a pre-release databases which is made available to the consortium members and a final database is made publicly available six months after the pre-release. Thus, for the purpose of calibrating a benchmark equilibrium database for our regional model, we plan to collaborate with CGTA.

4.0 EXPECTED OUTPUT

The proposed study is expected to be a path-treating attempt to provide a virtual dynamic regional model for study interactions among Africa economies as well as their interactions with the rest of the world. Out research results is also expected to contribute to public policy making for the various countries studied as well as for the continental policy making. This is in addition to contributing to existing knowledge and future research in macro modeling.

Indeed, our research output will be published accordingly and disseminated to the various professional economists and policy makers in the region and the rest of the world. Such policy –making institutions include United Nations, World Bank, International Monetary Fund, the African Development Bank, the African Union, Economic Community of West African States and African Economic Research consortium.

5.0 THE VIRTUALLY APPROACH

The Internet has greatly expanded the way in which large-scale economic models can be used and disseminated. Thus, our proposed on-time model will allow business forecasters, policy makers, and economics students to forecast the future, and, at the touch of a computer key, calculate the effects on the economy of related macroeconomic variables. Indeed, the virtual model will be a new tool for the web, allowing users to make changes, solve the model, examine their results and make further changes, without ever downloading anything to a personal computer. The web server does all the number crushing. Any or all of the data can be downloaded, printed, saved and shared with other users. When the user submits the input form, the data is sent to the server, which passes it to both modeling programs. These write their results into temporary files: the server reads these, reformats into HTML where necessary, pastes the chunks of HTML together into a complete page, and sends this back to the browser.

We plan to implement our model using CGI scripting. This is a technique, which causes the web server to run a “script” (a program written either as a batch file, or in a special-purpose scripting language) when a certain URL is requested. This script can do anything a batch file cards including running a program (such as a model) and sending back its output scripting languages have lots of facilities for string and file handling and can be very powerful. However, they also have disadvantages for example, their compiler does not do type checking and does not require variable declarations. This means that errors such as adding a number to a string, or using a misspell variable name can pass the compiler by; only to cause havoc at run time. For these reasons, we are proposing to use Java servlets.

Java is a general-purpose object-oriented programming language. It came to prominence in 1995, when its designers, sun micro-systems promoted it for writing applets-programs that can be downloaded from a web server and run on a web browser. This is “client-side programming” providing the user with downloadable Java code that will run on their browser. However, our virtual economy will use Java not for client-side, but for server-side programming. Here, the Java program runs on the web server, receiving data from the user and generating HTML pages graphs, and other content, which it sends back for the browser to display. The Java programs that do this are termed “servlets” by analogy with applets. Indeed, Java is less error-prone than other Programming Language. Another advantage is that servlets can call Java code from anywhere else. There are many excellent Java libraries available – some commercial, some free – or share ware – and using them can make one’s servlets much virtual engineering’s Java chart, for plotting out graphs and the support visual engineering offer. Portability is another advantage Java has been designed to run almost all programs unchanged on a wide range of machines and achieves this goal much better than did previous languages such as C++ and Fortran. In other words, Java makes it easier for us to move our code from one server to another.

In our proposed virtual economy mode, we will use two servlets. One-Model output – receives the string of data sent from the input form and returns the “Model Output” page which you will see on running the model. To do so, it will translate the users’ menus selection and writes them into a temporary file it then calls both the macro and micro models, picks up the results, converts into HTML where necessary, pastes these pieces of HTML into a complete output page and returns that to the server. The other servlet will handle graph plotting. When model output needs to place a graph in the output page, it cannot just include the binary data making up the image, because HTML does not work that way.

Instead, it needs to place an HTML IMG tag, which contains another URL pointing at the graph. Normally, this would point at a temporary file holding the graph. However, the URL need not pint at a file. Instead, it can refer to the script or servlet, which takes the graph's data points and generates the image on demand. This is what we intend to do. Model output generates a URL containing the data points, axis annotations and other graphical parameters. The URL will point at our plotting servlet. When the server receives this URL, it passes the data in it to the servlet, which decodes them and calls Java chart to generate the graph as an image file, which is then sent back to the browser.

Indeed, all web servers implement CGI but only a few, such as sun's Java web server can run servlets directly. Some servers that cannot, can still be equipped with "servlet adapters", which enable them to call servlets. Therefore, we intend running our virtual model on Windows NT using Netscape's enterprise server, coupled with New Atlanta communication's servlet Excel servlet adapter. However, we hope to consider other servers such as sun microsystem's Java and servlets; and freeware Apache server. Since, our proposed model is not the program, but the equations that product the economy's future state from its past history and the user's changes. These equations can therefore be run by any program capable of solving them. We propose linking to win-solve, general algebraic modeling system (GAMS) and GEMODEL.

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APPENDIX: THE AFRICAN ECONOMIES

S/NO	COUNTRY	INCOME PROFILE	REGION
1	SIERRA LEONE	LI	WA
2	NIGER	LI	WA
3	BURKINA FASO	LI	WA
4	GUINEA BISSAU	LI	WA
5	MAL	LI	WA
6	NIGERIA	LI	WA
7	TOGO	LI	WA
8	GAMBIA	LI	WA
9	BENIN	LI	WA
10	GHANA	LI	WA
11	MAURITANIA	LI	WA
12	GUINEA	LI	WA
13	SENEGAL	LI	WA
14	COTE D'IVORE	LI	WA
15	LIBERIA	LI	WA
16	CAPE VERDE	LI	WA
17	MOZAMBIQUE	LI	EA
18	ETHIOPIA	LI	EA
19	TANZANIA	LI	EA

20	BURUNDI	LI	EA
21	MALAWI	LI	EA
22	RWANDA	LI	EA
23	MADAGASCAR	LI	EA
24	UGANDA	LI	EA
25	KENYA	LI	EA
26	LESOTHO	LMI	EA
27	COMOROS	LI	EA
28	ERITREA	LI	EA
29	SOMALIA	LI	EA
30	SUDAN	LI	EA
31	CHAD	LI	CA
32	CENTRAL AFRICAN REPUBLIC	LI	CA
33	CAMEROON	LI	CA
34	CONGO (REP)	LI	CA
35	GABON	UMI	CA
36	EQUAT. GUINEA	LI	CA
37	SAO T. & PRINC	LI	CA
38	ZAMBIA	LI	SA
39	ANGOLA	LI	SA
40	ZIMBABWE	LI	SA
41	NAMIBIA	LMI	SA
42	BOTSWANA	LMI	SA
43	SOUTH AFRICA	UMI	SA
44	MAURITIUS	UMI	SA
45	DJIBOUTI	LMI	SA
46	SEYCHELLES	UMI	SA
47	SWAZILAND	LMI	SA
48	ZAIRE	LI	SA
49	EGYPT	LMI	NA
50	MOROCCO	LMI	NA
51	ALGERIA	LMI	NA
52	TUNISIA	LMI	NA
53	LIBYA	UMI	NA
54	CONGO (DEM. REP.)	UMI	CA
55	MAYOTTE	UMI	SA